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The University of Adelaide

REPORT

OF THE

WAITE AGRICULTURAL RESEARCH INSTITUTE

SOUTH AUSTRALIA

AND ASSOCIATED ACTIVITIES OF THE

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

1943-1947

ADELAIDE
AT THE HASSELL PRESS
1950

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The University of Adelaide

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The Waite Agricultural Research Institute

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Head of Department and Waite Professor of Agricultural Chemistry: J. A. Prescott, C.B.E., D.Sc.
Senior Soil Chemist: C. S. Piper, D.Sc.
Lecturer in Agricultural Chemistry: R. J. Best, D.Sc.
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Laboratory Assistants: R. D. Bond, C. S. Hocking.

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Plant Geneticist: A. T. Pugsley, M.Sc.
Assistant Plant Geneticist: G. M. E. Mayo, B.Ag.Sc.
Grassland Ecologist: R. L. Crocker, D.Sc. (on leave).
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Assistant Agronomists: A. J. K. Walker, B.Ag.Sc., N. S. Tiver, B.Ag.Sc., M.Sc., R. L. Specht, B.Sc. (temporary), P. F. Butler, B.Ag.Sc. (temporary).
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Scientific Assistant: Helen M. Ferres, B.Sc.
Technical Assistants: D. L. Parker, E. J. Leaney, D. L. Davies, S. R. Hockley.
Laboratory Assistants: Lynette M. Wright, Margaret R. Moyle, June R. Anderson, Janet Bartholomaeus.
Overseer at Yudnapinna Field Station: J. F. Cunneen.

Entomology:

Head of Department: D. C. Swan, M.Sc.
Entomologists: H. G. Andrewartha, D.Sc., H. W. Simmonds (part time).
Technical Assistant: Helen M. Brookes.
Laboratory Assistant: Ruth J. Burns.

Plant Pathology:

Head of Department: D. B. Adam, B.Ag.Sc.
Assistant Plant Pathologist: N. T. Flentje, M.Sc.
Laboratory Assistant: Janet E. Thomson.

Plant Physiology:

Plant Physiologist: L. A. T. Ballard, M.Ag.Sc., Ph.D.
Laboratory Assistant: Yvonne E. Rossiter.

Clerical Staff (for Waite Institute and C.S.I.R.):

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G. J. Snowball, G. R. Shirpurkar, L. C. P. Kerling, A. J. Antcliffe, D. J. Watson, Marion Watson, Christobel M. Williams.

Members of the Staff who have left for other Appointments since 1st January, 1943:

I. F. Phipps, B. S. Janes, A. E. Scott, C. A. N. Smith, Alison B. C. Vines, D. C. Wark, Nancy T. Burbidge, T. T. Colquhoun, J. R. Goode.

Council for Scientific and Industrial Research

Staff with Headquarters at the Waite Agricultural Research Institute (as at 31st December, 1947):

DIVISION OF SOILS:

Chief: J. K. TAYLOR, B.A., M.Sc., B.Sc.(AGR.)

Soil Physics Section:

Senior Research Officer: T. J. MARSHALL, M.Ag.Sc., PH.D.
Research Officers: G. D. AITCHISON, B.E., K. NORRISH, M.Sc., G. B. STIRK, B.Sc., J. P. QUIRK, B.Sc.(AGR.)
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Research Officers: A. C. OERTEL (Spectrography), M.Sc., J. T. HUTTON, B.Sc., H. C. T. STACE, B.Sc., B. M. TUCKER, B.Sc., R. S. BECKWITH, B.Sc.
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Soil Survey and Pedology Section:

Senior Research Officer: C. G. STEPHENS, M.Sc.
Research Officers: K. D. NICOLLS, B.Sc., B.Ag.Sc., K. H. NORTHCOTE, B.Ag.Sc., G. BLACKBURN, B.Ag.Sc., G. A. STEWART, B.Ag.Sc., T. LANGFORD-SMITH, M.Sc., R. A. PERRY, B.Sc.
Cartographer: P. D. HOOPER.
Junior Draughtsman: M. C. COULLS.

Note.—There are 4 Regional Centres—Hobart, Perth, Canberra, and Deniliquin permanently staffed with research officers of the Soil Survey Section.

Soil Microbiology Section:

Research Officers: MARGARET P. THOMAS, B.Sc. (on leave), J. R. HARRIS, B.Sc.
Assistant: BAYES LLOYD.

Guayule Rubber Investigations:

Research Officer (Chemist): R. E. SHAPTER, A.A.C.I.

COMMITTEE ON OENOLOGICAL RESEARCH:

(Chairman: PROFESSOR J. A. PRESCOTT, C.B.E., D.Sc.).
Senior Research Officer: J. C. M. FORNACHON, M.Sc.
Assistant: NADIA H. BRESSLER.

Division of Plant Industry (Gummosis Investigations):

(Under direction D. B. Adam, B.Ag.Sc., University of Adelaide).
Research Officer: Judith Grace, B.Sc. (Agr.).

Field Station: Division of Biochemistry and General Nutrition:
Technical Assistant: E. Talbot-Smith.

C.S.I.R. Officers who have left for other Appointments since 1st January, 1943:

J. S. Hosking, A. Walkley, Jean I. Arthur, H. R. Skewes, J. G. Baldwin, R. L. Crocker, A. J. Anderson, T. H. Strong.

The Waite Agricultural Research Institute

1. Introduction.

The foundation of the Waite Institute was made possible as a result of the gift of Peter Waite to The University of Adelaide of land and property at Glen Osmond, together with an endowment.

It was in October, 1913, that Mr. Waite first intimated to the University Council his desire to establish the Institute and from that time till his death in 1922 he took a personal interest in the scheme to be developed. In 1915 he purchased Netherby Estate (112 acres) and Claremont (53 acres) adjoining his estate of Urrbrae, making a total of 299 acres to be given to the University for the Institute, in addition to 114 acres to the South Australian Government for an Agricultural High School. How clearly he had in view the purpose which has been carried out may be seen from this paragraph in a letter to the Chancellor, dated 21st May, 1915:

> "There are in South Australia large areas of proved agricultural land with a rainfall suitable for Closer Settlement. In recent years many of the large holdings have been divided up, and also some of the smaller, and it is reasonable to suppose that this process of subdivision will be continued as scientific discoveries render possible the more intense cultivation of the soil, which will thus be able to sustain a larger population. Help is also required from scientific research to satisfactorily deal with the large area of somewhat inferior mallee wheat land, as well as to discover what grasses, herbs, and shrubs may be acclimatized to advantage in the vast tracts of pastoral country, which have but a small and erratic rainfall."

The landed estate came into possession of the University in 1922 and with it a number of shares in Elder, Smith & Co., Ltd., which realized the sum of £58,450. The total value was estimated at £100,000; the annual Government subsidy of five per cent. amounted to £5,000, and work began with an income of about £8,000.

In May, 1923, the University Council resolved that the estate be given a name that defines the function, namely, "The Waite Agricultural Research Institute". The first appointments to the staff were made in 1924 and 1925.

The University purchased 80 acres of the Springfield estate adjacent to Netherby in 1935 and 10 acres of Alverstoke—known more recently as Urrbrae Park—in 1948 for the purposes of the Institute.

The three first laboratories were those endowed by the late Sir John Melrose, the family of the late John Darling and the family of the late Ranson Mortlock. A fourth laboratory was completed in 1947, with the assistance of an advance of £9,602 from the Commonwealth Government as part of the Rehabilitation Scheme for the education of ex-servicemen.

In addition to the laboratories, a range of glasshouses, two implement sheds, a woolshed, and a cereal barn have been erected since 1925. The glasshouses include two designed for general work in agronomy, plant pathology, and physiology and one designed for entomology.

Since 1927 the Division of Biochemistry and General Nutrition of the Council for Scientific and Industrial Research has maintained at the Waite Institute a field station equipped with feeding pens and a laboratory. Here certain problems in the nutrition of sheep, requiring relatively large numbers of animals, are investigated.

Since 1929 the Waite Institute has been the headquarters of the Division of Soils of the Council for Scientific and Industrial Research.

Endowments subsequent to the original one of Peter Waite have included those of the late Mrs. Elizabeth Macmeikan, and the late Mr. Hugh Hughes. The Ranson Mortlock Trust Fund was established in 1936 by the family of the late Mr. Frederick Ranson Mortlock for research in connection with the regeneration of pastoral lands in the more arid regions. Mr. J. T. Mortlock has subsequently generously supported these investigations with special donations.

Apart from its original and subsequent endowments the Institute derives its main income from appropriations under Acts of Parliament of South Australia.

Under the original deed of gift it was provided that portion of the area containing 67 acres should be held in perpetuity as a public park. Effect has been given to this provision by the establishment of an arboretum in which trees can be grown to demonstrate their value for shelter and ornament, and their adaptability to the local soil and climate. More than 1,000 trees in all, belonging to 450 different species, have been planted since 1928.

The library of the Waite Institute is designed to meet the needs of research, and the policy is to make it as complete a reference library as possible on matters relating to the field of agricultural science. The present total of books is 2,500, and of bound periodicals 4,200, with an additional 35,000 serials and pamphlets.

From the beginning of 1925 until early in 1938 the Waite Institute was under the direction of Dr. A. E. V. Richardson. To Dr. Richardson and to the late Sir Walter Young (who was Chairman of the Finance Committee of the University from 1927 to 1935), the Waite Institute is deeply indebted for the progress made during the early years of its establishment.

Professor James Davidson, head of the Department of Entomology, died in August, 1945, and was succeeded in July, 1946, by Mr. D. C. Swan. The late Professor Davidson was noted for his contributions to our knowledge of insect ecology, bioclimatology and the growth of animal populations.

Dr. I. F. Phipps, Plant Breeder and Geneticist, resigned in 1946 in order to take up an appointment with Imperial Chemical Industries of Australia and New Zealand, Ltd. He has been succeeded by Mr. A. T. Pugsley. Dr. L. A. T. Ballard was appointed to the position of Plant Physiologist in 1946, and Mr. R. L. Crocker to the position of Grassland Ecologist in 1945.

During the five years under review experimental work has been conducted at country centres with the goodwill and co-operation of a number of individuals and organizations. It is a pleasure to record such assistance from the following: Messrs. F. Coleman and Sons, Saddleworth; Mr. R. L. Davidson, Pallamana; Roseworthy Agricultural College; Government Experimental Farm, Kybybolite; The Renmark Irrigation Trust, and in particular Mr. J. S. Tolley; the Yalkuri Pastoral Company, and in particular Messrs. L. M. Har-

vey and K. Bakewell; Mr. N. Brookman, Meadows; the Staff of the Australian Wheat Board; Mr. G. Falland, Renmark; Mr. H. C. Kempe, Lindsay Point, via Renmark; Mr. F. R. Humphris, Jamestown; Mr. G. R. Schiller, Hammond, Mr. H. O. Abbott, Bruce; Mr. L. W. Gare, Mt. Bryan East; Mr. K. L. Blesing, Gladstone; Mr. B. Young, Owen; Mr. F. P. Short, Paradise; Messrs. Peucker, Mt. Gambier; Mr. A. H. Shearer, Waitpinga; Mr. A. Hannaford, Waitpinga; Mr. L. S. Ekers, Mt. Compass; Mr. D. N. Chapman, Houghton; Mrs. S. N. Kidman, Naracoorte; Mr. L. R. DeGaris, Naracoorte; Mr. D. P. Gericke, Naracoorte; Mr. J. Clezy, Naracoorte; Mr. J. F. B. Porter, Naracoorte; Mr. R. M. Williams, Lochaber; Mr. A. Major, Lochaber; Mr. T. Butler, Lochaber; Mr. R. Reschke, Coonawarra; Mr. P. G. Loechel, Lucindale; Mr. R. I. G. Hawkes, Lucindale; Mr. R. J. Legoe, Lucindale; Mr. A. Grieve, Avenue Range; Mr. R. Somerville, Penola; Mr. J. Rymill, Penola; Mr. M. Lambert, Penola; Mr. R. Pahl, Penola; Mr. R. Cummings, Penola; Mr. N. Gurr, Penola; Mr. A. Cameron, Millicent; Mr. G. Cameron, Beachport; Mr. D. C. Cowell, Kalangadoo; Mr. C. S. Hall, Wynarka; Mr. H. W. Petras, Karoonda; Mr. Bert Boehm, Lights Pass; Mr. L. J. Wicks, Highbury; Mr. W. Smith, Angaston.

2. Scientific Work of the Institute.

The period under review covers the closing years of the second world war and apart from the influence of many staff enrolments and secondments for special duties, much of the work of the Institute was consciously directed to the solution of problems arising directly out of the war situation. Reference may be made here to the work on flax production, the growing of the Mexican rubber plant, guayule, and the study of the insect pests of stored grain.

The scientific work of the Institute is centred round the study of the principles of crop and pasture husbandry, and of the problems which may be associated with this aspect of agriculture. Animal husbandry is not a feature of the work of the Institute except in so far as it is necessary for the study of pastures. The main subjects of investigation may be included in the following groups:

Agronomy, Agrostology, and Plant Genetics.

The investigation of the factors affecting the production of farm crops; the improvement, establishment and management of pastures; the improvement of cereals and fodder plants by hybridization and selection; the identification and control of weeds.

Plant Physiology.

The investigation of the metabolism and growth of plants of agricultural importance. The study of growth-regulating substances.

Plant Pathology.

The investigation of the diseases of agricultural and horticultural crops and of forest trees.

Entomology.

The investigation of the insect pests of agricultural and horticultural crops, of stored products and of forest trees.

Agricultural Chemistry.

The classification of soils; the investigation of soil fertility problems; the chemical study of plant viruses; the chemical study of pastures.

Under the terms of the appropriate Acts of Parliament the Waite Institute, in addition to its principal function of research, provides scientific advisory services in systematic botany, plant pathology and entomology to the Minister responsible for the Departments of Agriculture and of Woods and Forests. The University of Adelaide maintains a School of Agricultural Science and in conjunction with Roseworthy Agricultural College provides courses of instruction leading to the degree of B.Ag.Sc. Of these courses those in the third and fourth year in agriculture, agricultural chemistry, mycology, plant pathology and entomology are provided at the Waite Institute. Facilities are provided in the several departments for post-graduate training leading to the higher degrees.

The later years of the period under review saw a considerable increase in the numbers of students entering the Faculty of Agricultural Science. A substantial proportion of these students are ex-servicemen under the Commonwealth Reconstruction Training Scheme.

The Work of the Institute

Agronomy, Agrostology, Plant Breeding and Genetics

The natural resources of the South Australian environment have been investigated in terms of climatic and soil factors, together with possible modifications of land use and management in relation to these. The approach to the problems involved has proceeded along the lines of survey, followed by detailed researches at specific centres chosen to represent areas characterized by a defined range of conditions.

While each problem has tended to appear at the outset as a practical issue, the programmes of research have been conducted with a view to the establishment or substantiation of scientific principles, relating to both the problem itself and the practical methods by which economical improvement can be devised.

The improvement of the plant material available for agricultural and pastoral production has been sought through introduction, comparative tests in the field and through selection and breeding. Such methods have been applied to standard field crops, such as the cereals and peas, possible new crops and a wide range of herbage plants.

In addition to the above the improvement of short term and long term methods of land management has been sought.

Pastures have received special attention from the earliest years of the Institute because the future use of both naturally poor soil receiving abundant rainfall and land devoted previously to wheat production will depend largely on substantial improvement of the soil. This can only be achieved with economy through the medium of seeded pasture incorporating productive herbage legumes.

Among crops new to the State and carried to the stage of commercialization or extended trial under practical conditions of farming are flax, linseed, safflower and guayule.

The work has been conducted mainly in the field with ancillary studies in pot cultures under glasshouse conditions and in the laboratories.

The researches have been located at the Waite Institute as a main centre where the more detailed and long term programmes have been followed; but outside country centres have been drawn on freely to ensure that the main future agricultural regions of the State have been appropriately sampled. These have covered:

(a) Soils of naturally low fertility receiving liberal and assured rainfall.
(b) Irrigated and irrigable areas.
(c) The main wheat growing area.
(d) Marginal land.
(e) The northern pastoral region.

1. FIELD CROPS.

Field investigations have been conducted at the Waite Institute since 1925 to test the influence of different crop rotations, fertilizer and cultural treatments on the yield of wheat and associated crops. Field tests with wheat, oats, barley, peas, flax, linseed and safflower have served as a prelude to subsequent breeding work.

A rotation experiment commenced in 1925 has been maintained, with a few modifications, as a project of long term duration. Yield data from this trial has been recorded over a continuous period of 23 years and the summarized records for the seasons 1926–47 appear on pages 83 and 84.

Modern methods of replicated design were introduced into all new field experiments from 1927 onwards. Since 1937, most attention has been paid to the design of new systems of crop rotation; the influence of peas and sown pastures on crop yields, and the effects of fertilizer treatment in association with crop rotation on both short term production and the trend of soil fertility, have occupied a prominent place in this work.

1. Permanent Rotation Experiment.

This experiment includes comparison of 11 systems of crop rotation, in which the principal crop is wheat. All courses of the 11 systems appear in every year, so that the effects of each season upon the crops sown can ultimately be determined.

The mean yields of total produce grown for the period 1926–42, together with the yields for the individual seasons 1943–47 and the mean yields for the full period in the experiment to date, 1926–47 are presented in Table 1, pages 83 and 84.

The four-course rotation of wheat-oats-pasture-fallow has continued to produce higher yields of wheat, oats and pasture than all rotations of shorter duration. The mean yields of the main crops in a selected series of rotations are shown below.

	Wheat (bush.).	Peas (bush.).	Oats (bush.).	Winter pasture (cwt. air dry).	Sudan grass (cwt. green).
Wheat continuously	14·70	—	—	—	—
Wheat, peas	26·31	20·37	—	—	—
Wheat, bare-fallow	34·39	—	—	—	—
Wheat, Sudan grass	33·15	—	—	—	23·93
Wheat, oats, fallow	35·72	—	42·58	—	—
Wheat, oats, peas	31·72	29·28	36·98	—	—
Wheat, oats, pasture, fallow	44·88	—	54·40	32·76	—

Compared with the position as at the end of 1942 the mean yield of wheat in the above rotations with only 1 or 2 crops has decreased; on the other hand, the yield of wheat in the 2 rotations with 3 crops, has improved.

The yield of oats and pasture has also improved since 1942 in the four-course rotation.

Those rotations which do not include a year of fallow have tended to become increasingly infested with weeds.

The experiment has emphasized the value of four-course rotations compared with those of shorter duration in maintaining soil fertility and it has led to the investigation of alternative four-course rotations under varying fertilizer treatment.

2. Investigations on Forage Crops and Temporary Pasture in Four-course Rotations with Wheat.

To compare the value of different forage crops in maintaining soil fertility, a rotation experiment was commenced in 1937 on land which had been heavily cropped. The forage crops were incorporated in four-course rotations of the pattern fallow, wheat, forage crop, Wimmera rye-grass pasture; and the yields of wheat under these systems were compared with the yield of wheat in fallow-wheat rotation. The rotations were as follows:

A	*B*	*C*	*D*	*E*
Fallow	Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat	Wheat
Peas	Clover	Barley	Oats	Fallow
Pasture	Pasture	Pasture	Pasture	Wheat

Superphosphate was applied to all crops and to the pasture. Half of each plot sown to forage was harvested each year and the produce removed whilst the other half-plot was grazed. The pasture was grazed twice in each season, yields being obtained by sample cuts prior to grazing.

By 1947 two complete cycles of each phase of the four-course rotations had been completed and the results were statistically analysed. The principal tables of comparisons are given on pages 85 and 86.

Field peas has proved to be the outstanding forage crop, averaging 46·1 cwt. of air dry forage on the grazed sections, and 39·8 cwt. of total crop, including 30·3 bushels of grain, on the harvested sections over eight seasons 1937–44. The yield of peas forage was about double the yield of each of the other forage crops; the reliability of the crop, its protein value, and effect on soil fertility, render field peas by far the most valuable forage crop for conditions comparable to those at the Waite Institute. Subterranean clover was not successful as a one-year forage; barley and oats failed to produce high yields under the depleted fertility level of this land, and it is certain that such crops would do little to restore fertility unaided. Following the completion of two cycles under the original design, the rotations have been modified; oats receiving sulphate of ammonia has replaced barley and, in place of clover, peas, followed by oats for pasture has been introduced.

Marked and highly significant differences were found in the yields of Wimmera rye-grass pasture following the various forage treatments; in all cases significantly greater yields were obtained after grazing than after harvesting the previous forage crop. The mean yields of pasture for eight years 1938–45 were 51·4 cwt. after grazed peas and 33·4 cwt. after harvested peas, compared with 14·4 cwt. and 10·7 cwt. after oats, grazed and harvested respectively.

The yield of wheat in each of the four-course rotations was significantly higher than in the fallow-wheat rotation. Over all rotations, grazing the forage crops significantly increased the yield of wheat compared with harvesting the forage crops, although within individual rotations the differences were not significant. The mean yields of wheat in the peas rotation for the period 1940–47 were 42·5 bushels of grain and 64·7 cwt. of total produce, representing increases of 10·6 bushels and 19·4 cwt. over the fallow-wheat rotation. These figures are a measure of the fertility building power of field peas when grown in rotation with wheat.

The principal effect of the pea crop appears to have been to increase the level of available nitrogen in the soil. The nitrate content of the soil at the conclusion of the fallow period was determined during 1940–43 for each rotation, and the nitrate nitrogen contents (p.p.m.) to 18 inches depth were as follows:

	ROTATION.				
	A	*B*	*C*	*D*	*E*
Grazed section	17·8	15·4	13·8	13·0	11·5
Harvested section	15·1	13·7	12·5	11·6	11·5

In 1946 determinations were made of the degree of soil aggregation at the conclusion of the pasture phase of rotations *A* and *D* and after wheat in rotation E. The peas rotation was shown to have increased the percentage of water stable aggregates to a small and barely significant extent compared with fallow wheat.

3. Combined Rotation and Fertilizer Experiment.

In 1936 and 1937 four crop rotations, each involving four courses, were commenced to investigate the effects of nitrogen, phosphate, and lime on the yields of crops, and the residual effects of the fertilizers on pasture. The rotations were as follows:

A	*B*	*C*	*D*
Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat
Peas	Oats	Barley	Wheat
Pasture	Pasture	Pasture	Pasture

The experimental design consisted of 16 blocks, enabling each course of the four rotations to occur every year. Each block was divided into 27 plots, and was either sown or fallowed uniformly according to the rotation and its phase.

Superphosphate and nitrogen, both at 0, 1 and 2 cwt. per acre, and lime at 0, 2½ and 5 cwt. per acre were applied at seeding to all crops on a $3 \times 3 \times 3$ factorial design. No fertilizers were applied to the pasture which comprised a mixture of subterranean clover, barrel medic, and Wimmera rye-grass. The crops were harvested for yield of total produce and grain and the pastures were sampled for yield of dry matter prior to being grazed by sheep.

The results for two complete cycles of this experiment have been analysed, and the experiment terminated. The more important tables are set out on pages 86–89, and the main conclusions to be drawn from the investigation are given below.

Effect of Rotation.

Differences between rotations, in terms of the yield of wheat on fallow and the yield of pasture, were most pronounced in the case of the latter; rotation *A* yielded 6–6½ cwt. per acre more dry matter than rotations *C* and *D*, which in turn yielded 6–6½ cwt. more than rotation *B*. The mean yields of wheat grain from the four rotations did not differ significantly, but rotation *A* yielded significantly more total produce than the other rotations.

Fertilizer Effects: Wheat on Fallow.

The grain yield of wheat on fallow in all rotations was improved to a significant degree by the application of either 1 cwt. or 2 cwt. per acre of superphosphate, the differences being of the order of 4–8 bushels per acre. Although the yield of grain with 2 cwt. per acre of superphosphate was not better than the yield with 1 cwt. per acre, the yield of total produce with 2 cwt. per acre was significantly better than with 1 cwt. per acre over all rotations and for the individual rotations *B* and *D*.

An interesting feature was that over all rotations nitrogen improved the yield of wheat on fallow; in the case of grain yields 2 cwt. per acre of sulphate of ammonia gave a significantly greater yield than either nil or 1 cwt. per acre. In rotation *A*, including peas harvested for grain, nitrogen had no effect on the yield of wheat grain, but 2 cwt. per acre significantly increased the total produce.

Lime improved the yield of wheat grain when applied at the rate of either 2½ or 5 cwt. per acre, but had no effect on the yield of total produce.

There were no significant interactions between the different fertilizers.

Stubble-sown Crops.

Superphosphate applied to peas at either 1 cwt. or 2 cwt. per acre greatly improved the yield of both total produce and grain; the increases were of the order of 12–14 cwt. and 7–8½ bushels per acre respectively. The differences between 2 cwt. and 1 cwt. of superphosphate were not significant and favoured the higher dressing in the case of total produce and the lower dressing in the case of grain. Lime had a small significant effect on the yield of grain and total produce; nitrogen as sulphate of ammonia had no effect.

The responses to fertilizers of the cereals wheat, oats and barley when sown on stubble were similar and may be considered together. The outstanding fertilizer effects with these stubble crops were the large responses to nitrogen, and the interaction of nitrogen and phosphate. Yields of total produce (cwt. per acre) and grain (bushels per acre) with different levels of nitrogen were as follows:

		Sulphate of Ammonia.	
	Nil.	1 cwt. per acre.	2 cwt. per acre.
Oats T.P. (cwt.)	45·3	60·1	72·4
Grain (bush.)	46·1	59·6	68·8
Barley T.P. (cwt.)	36·1	45·5	52·7
Grain (bush.)	35·7	43·5	49·1
Wheat T.P. (cwt.)	36·8	44·6	52·4
Grain (bush.)	26·2	30·3	33·9

In the absence of applied nitrogen, superphosphate tended to reduce the yield of both total produce and grain, particularly when applied at 2 cwt. per acre; significant decreases were recorded for oats grain and for barley total produce, but in the other cases the decrements were not significant. Where either 1 cwt. or 2 cwt. per acre of sulphate of ammonia was applied all crops responded to phosphate, but the yield with the 2 cwt. dressing of superphosphate was never significantly better, and was sometimes significantly lower than with 1 cwt. of superphosphate. A clearer picture of this highly important interaction is obtained from an examination of the following table of grain yields (bushels per acre).

	No Nitrogen.			2 cwt. per acre Sulphate of Ammonia.		
Superphosphate.	Nil.	1 cwt./acre.	2 cwt./acre.	Nil.	1 cwt./acre.	2 cwt./acre.
Oats	47·1	47·3	43·8	63·6	71·5	71·2
Barley	37·0	34·9	35·2	45·5	52·1	49·7
Wheat	26·3	26·4	25·8	29·3	36·5	35·9

The significance of these results is of far-reaching importance. The amount of available nitrogen in the soil after a wheat crop on the average farm in South Australia is probably not higher than in this experiment, so that the application of superphosphate to stubble sown crops can rarely result in increased yields under present fertility levels, and may actually lead to a decrease in yields.

The stubble sown cereals did not respond to lime.

Pasture: The residual value of superphosphate is shown in the yields of the unfertilized pasture. Superphosphate at 1 cwt. and 2 cwt. per acre compared with no superphosphate, applied to the previous crops, increased the yield of pasture by 3 and 6 cwt. per acre of dry matter, over all rotations. For individual rotations the differences were of similar order and were significant in all cases. Lime applied to preceding crops also improved the yield of pasture, the increment in yield due to 2½ cwt. per acre was significant over all rotations and for each rotation. The further increment due to 5 cwt. per acre was significant over all rotations taken together, but only for rotation *C* when considered individually. The interaction between lime and phosphate applied to previous crops produced significant effects, the value of previously applied phosphate was greatly increased where lime had also been applied with the previous crops, possibly because the phosphate had been fixed in a more available form in the soil of these plots.

4. Investigations on the Residual Value of Superphosphate.

Arising from the wartime shortage of superphosphate, an investigation was carried out on the nature and value of residual phosphorus resulting from previous applications to crops on the principal wheat-growing soils of South Australia. The chemical aspects of the investigation are dealt with elsewhere in this report, and it is sufficient here to indicate the principal agronomic results.

On slightly acid red brown earth soils, such as those of the Waite Institute fields, it was found that superphosphate applied with previous crops has a considerable residual value; where amounts of the order of 15 cwt. per acre or more have been applied, the yield of wheat grain responds little, if at all, to superphosphate applied with the current crop. On alkaline red brown earths and on solonized brown (mallee) soils, where a higher proportion of the residual phosphorus is fixed by reaction with calcium, the residual value of previous superphosphate dressings is greater, and only very small increases in yield due to applied phosphate are likely on soils which have received a total of about 10 cwt. per acre of superphosphate in previous years.

The manner in which the response of wheat to current superphosphate dressings diminishes as the soil phosphorus status is improved is illustrated in the following table of results of some field experiments carried out at the Waite Institute.

Year.	Previously applied Superphosphate.	Increased yield of wheat (bushels per acre) due to current superphosphate compared with no fertilizer.		
		46 lb. per acre.	92 lb. per acre.	184 lb. per acre.
1925	nil	6·9	12·2	15·5
1926	nil	9·8	13·9	17·1
1945	9½ cwt.	2·9	3·2	4·9
1945	19½ cwt.	—1·3	0·6	—0·3

An examination of phosphorus uptake by wheat in South Australia has revealed that an average 20-bushel crop removes about 7 lb. of P_2O_5 per acre, equivalent to approximately 40 lb. of superphosphate (22%). Therefore, from the point of view of maintaining the phosphorus status of the soil and the long term yields of wheat, it is important that the rate of superphosphate application should not be reduced below ½ cwt. per acre, even on soils which have attained a high phosphorus status through accumulated residual phosphorus. On the other hand dressings greater than 1 cwt. per acre would appear to be unnecessarily wasteful.

5. Time and Rate of Seeding Trials with Field Peas.

Field peas have consistently given high yields of forage and grain at the Waite Institute, but farmers' crops in the better cereal districts have often yielded poorly. It was thought that the frequent delay in the seeding of peas until wheat and other crops had been sown might in part be responsible. In 1944 a field experiment was commenced to investigate the effects on yield of sowing White Brunswick peas in mid-May, mid-June and early July at 60, 90, 120 and 150 lb. of seed per acre. The experiment has been repeated for four seasons and will be concluded after a further year. Yields for the period 1944–47 are given on page 90.

In three of the four years early sown peas outyielded the later seedings, and over the four seasons the mean differences in favour of early sowing, compared with mid-season and late sowing, were about four and eight bushels respectively. In 1944, when rainfall was low and the early spring was exceptionally dry, the differences were very marked; early sown peas yielded 21·6 bushels and the late seeded crop only 2·3 bushels. On the other hand, in 1947, with heavy spring rains, the yields from all treatments were high and the mid-season and late crops outyielded the early seeding by about seven bushels per acre. Early seeding appears desirable where the rainfall from late August onwards tends to be light or uncertain.

The importance of seed rates has varied with the time of sowing; in the case of early sown crops there was little difference in yield with different rates; with mid-season and late sowing heavier seed rates improved yields.

2. PLANT BREEDING AND GENETICS.

Perhaps the most important aspect of disease control by the use of resistant varieties of plants is the possession of an adequate knowledge of the various "resistant" genes used in the breeding programme. Genetic studies during the past five years have been planned with the object of adding to our knowledge of the inter-relationships between "resistant" genes and the physiological races of the pathogens concerned.

Breeding work has been re-orientated in such a way as to make full use of the backcross method in rectifying single faults in our standard crop varieties. The task of developing stem rust resistant strains of ten standard wheat varieties has been completed and their value was strikingly demonstrated during the 1946 and 1947 rust epidemics.

As the development of a more efficient system of agriculture involves a greater degree of diversification, both of crop and herbage plants, increased attention has been devoted to the introduction of new material of possible economic value in the South Australian environment.

1. Cereals.

(i) Wheat.

(a) *New Varieties.* The Nabawa × Hard Federation (37–443) crossbred referred to in earlier reports was released to farmers in February, 1944, under the name of Ridley. Ridley is a high-yielding, good quality wheat, mid-season in maturity and recommended for those areas of the State where Ranee does well.

Nabawa × (Riverina × Hope) (39–129) which has been mentioned in previous reports, continued to yield well during the seasons under review. With its high resistance to stem and leaf rust it attracted attention during the 1946 and 1947 epidemics and as a result it has been released under the name Glenwari.

Warigo, released by the Waite Institute in 1941 is steadily gaining in popularity as a standard South Australian wheat variety. It was ranked as the second wheat in the State in 1947, when 175,000 acres were sown.

New varieties from other States that have been tested include Bungulla, Celebration, Charter, Diadem, Frisco, Gabo, Insignia, Kendee, Kondut, Koorda, Pinnacle and Yalta.

(b) *Crossbred material.* The later strain (38–356) of Nabawa × (Riverina × Hope) has been maintained in trials at the Waite Institute. Although of better baking quality than the earlier strain (39–129) results do not yet indicate any rôle justifying its release.

The rust-resistant crossbreds resembling Ghurka and Ranee were selected for country yield trials in 1945 and compared more than favourably with the parent varieties. Three strains (Gluyas × Hope) × Ghurka^3 (43–46), (Gluyas × Hope) × Ranee^2 (42–79) and (Gluyas × Hope) × Ranee^3 (43–28) have been retained in country trials for further testing.

Two strains of stem rust resistant crossbreds, Kenya C.6042 × Dundee (40–109) and Kenya C.6042 × Ghurka (41–142), have also been included in these trials, the former since 1943 and the latter since 1945. Those crossbreds deriving their stem rust resistance from Kenya C.6040 have been withdrawn from the replicated yield trials since their gene for resistance has been shown to be ineffective against the new biotype of race 34 of *Puccinia graminis tritici*, identified in 1942.

A complicated Ghurka crossbred (43–62), derived from both Kenya C.6042 and Gluyas × Hope was included in the country trials for 1947.

(c) *Yield Trials.* Yield trials have been continued at the Waite Institute and at Saddleworth. In 1944, an additional series of plots were established at Pallamana. The results of these trials are tabulated on pages 91–93 and 95–96.

(d) *Disease resistance.* A backcross programme having as its objective the production of disease resistant strains of standard varieties was commenced in 1942. Eureka and Gabo were the sources of genes for resistance to stem rust and a parallel series of projects was conducted using these wheats. With the appearance of a new race of stem rust in Australia capable of attacking Eureka and its derivatives, attention has been centred on utilizing the resistance of Gabo. The work with ten varieties was completed in 1946 and seed stocks are being built up prior to releasing the new varieties to farmers.

Oro, Doubbi, White Federation 38 and Selection 1403 have been used as resistant varieties in the breeding work with bunt resistance. Genetic studies have indicated the value of genes from these varieties in controlling the various races of the pathogens *Tilletia foetida* and *T. caries.* This work is proceeding.

(ii) *Barley and Oats.*

Prior barley is the most widely grown malting variety in South Australia and accounted for 65 per cent. of the total acreage of the State in 1947. It is, however, highly susceptible to powdery mildew (*Erysiphe graminis hordei*) and to covered smut (*Ustilago hordei*). The backcrossing procedure has been used to incorporate genes for resistance to these diseases using the resistant variety Kwan as the non-recurrent parent in both instances. The mildew resistant gene Ml_k has been transferred to Prior and seed stocks of the new resistant strain are now available. Smut resistant selections of the cross Kwan $\times$ Prior[4] have been obtained.

Several collections of *Ustilago hordei* from various parts of Australia have been identified as closely resembling Tapke's race 5. Genetic studies have indicated that Kwan contains at least two dominant genes for resistance to this race.

The newly-released malting variety Research from Victoria yielded well in the 1943 and 1944 trials at the Waite Institute and, during the severe wind storms which did so much damage to crops in barley districts of the State, this variety suffered little.

Grain germination studies have been made with a number of barley varieties. The results have shown that the developing barley grain is able to germinate when quite immature but, with progressive ripening, a dormant stage is reached so that an "after ripening" period is required before the seed can be regarded as being mature. The time required for these processes was found to vary considerably from variety to variety.

The work on oats has been restricted to a small project examining the possibility of incorporating early vigour in a late Welsh oat.

(iii) *Peas.*

The value of peas as a crop in the rotation programme in cereal districts of South Australia has been established. Selection and breeding work has been commenced to investigate the possibility of producing early maturing varieties that will enable peas to be grown in districts receiving an average annual rainfall of less than 18 inches.

A survey of existing varieties was first undertaken and a number then selected for breeding and selection. In 1943 replicated variety trials were commenced and have since been repeated each year. There has been a markd differential response of varieties to the fluctuating seasonal conditions from year to year. The results of these trials are tabulated on pages 97–98.

2. Fibre and Oil-Bearing Plants.

(i) *Flax.*

Varietal testing of existing and newly-introduced varieties, in close collaboration with the Commonwealth Flax Production Committee, has been continued. This committee has been able to define problems in need of investigation. At the Waite Institute, three breeding projects have been commenced:

(a) *The production of rust resistant varieties.* Three varieties of Russian origin, Stakhanovetz, D.83 and 806/3, have been shown to be resistant, and each returned high straw and fibre yields in trials at the Waite Institute in 1946. Wada, a Western Australian variety released in 1946 and showing good yield and quality of fibre, was also shown to be resistant to rust at the Waite Institute. Other resistant varieties are Cascade and Saginaw × Ottawa from the United States of America.

The latter derives its resistance from Ottawa 770B and has been used as a parent in crosses with present day commercial flaxes. The yield and fibre quality of the resulting crossbreds are now being tested.

(b) *Rapid winter growth.* The present varieties grow slowly during the early stages and offer little competition to the more aggressive weeds. Use is being made of the Egyptian variety, Beladi, a rapid winter grower, and selections from Beladi crosses are being carried on.

(c) *Dual purpose flaxes.* Several selections of Liral Crown × Walsh × Liral Crown, together with an unnamed crossbred from England, Bison × Liral Prince, were included in the 1945 and later trials. The straw and fibre yields from them were equal to those obtained with the fibre varieties, and in addition the seed yields were higher by up to 20 per cent. These tests are continuing to determine whether high fibre and high seed yields can be incorporated in a single variety.

(ii) *Linseed.*

Earlier reports have indicated the general superiority of Walsh and Punjab linseed varieties over others that have been tested. Walsh, with proven resistance to rust under South Australian conditions, was selected as an appropriate parent when a commercial linseed growing project was launched in 1947. Its resistance has been incorporated in several crossbred lines, two of which, Punjab × Walsh (46–115) and a backcross Punjab type (46–138), have been bulked for further yield trials.

Losses from Cutworm moths (*Heliothis armigera*) were severe in 1944, and rust reduced the yields of susceptible varieties in 1944, 1946 and 1947. In recent years, the damage from birds has become so serious that it has not been possible to measure the yields from some plots. Semidehiscent varieties like Walsh are much more subject to attack than nondehiscent varieties such as Punjab.

Through the courtesy of Messrs. Meggitt Limited, oil yields and iodine values have been obtained each year. Oil contents have varied rather widely from season to season, Punjab 5 ranging from 39·34 per cent. in 1945 to 43·4 per cent. in 1943 and Walsh from 38·91 per cent. in 1944 to 42·5 per cent. in 1943.

(iii) *Safflower.*

Australia's difficulty in importing drying oils has focussed attention on local substitutes for linseed oil. The oil of safflower suggested itself as such a substitute and, in 1940, investigations on the cultivation of safflower as a crop were begun. In close collaboration, the Commonwealth Munitions Supply Laboratories investigated the oil of this plant.

Preliminary work in the first four years of the investigation has shown that safflower is capable of growing and yielding well as a winter sown crop in southern Australia; dry conditions in spring are withstood. The crop can be sown and harvested with the same machinery as that used for wheat.

The Indian large seeded variety, Niphad 630, has been initially employed as a standard. American, Russian, Indian and Egyptian varieties have also been imported and included in a series of variety trials begun in 1944. Yields of high quality seed which compare favourably with other parts of the world have been obtained. Three of the newly introduced varieties, Russian, C.P. (Acqun. 20) and Egypt (Acqun. 21) have been incorporated in further trials.

It has been shown that safflower plants develop an extensive root system, penetrating to depths of up to seven feet.

The results, generally, indicated that the emergence of the safflower seedling is slow so that, in the early stages, the crop is susceptible to dry conditions on the one hand and setting of the soil by heavy rains on the other. Furthermore, weed infestation at this stage is a secondary manifestation of the same problem. As part of the approach in this phase of the investigations, a series of replicated time and rate of sowing trials was begun in 1946.

The work of the Commonwealth Munitions Supply Laboratories has shown that the oil content of safflower may vary from 22 to 37 per cent. The oil is characterized by the absence of any appreciable quantities of linolenic acid and can replace linseed oil in most organic coating compositions.

The investigations are proceeding.

3. Vegetables.

(i) *Potatoes.*

Co-operative experiments with the Department of Agriculture were concluded in 1944 with yield trials at Ashbourne and Woodside. The results obtained were not significant but the superiority of Katahdin and Sebago to standard varieties, indicated in earlier trials, was not maintained.

A separate trial indicated that virus free Up-to-date yielded better than certified Up-to-date.

(ii) *Tomatoes.*

Leaf mould resistant work has been continued and, although resistant strains of suitable commercial quality have been secured, they have proved more susceptible to mosaic disease than the standard Dwarf Reds and, for this reason, they cannot be released until this fault is rectified.

3. PASTURES.

Investigations of the factors concerned in pasture improvement have formed a major part of the work in agronomy and agrostology from the earliest years of the Institute.

The analyses of climatic variables and their relation to growth and drought resistance of herbage plants, together with the information resulting from soil surveys and work in plant nutrition, have provided a useful foundation for the examination of pasture problems on a regional basis.

At the Waite Institute, emphasis has been placed on the introduction and testing of new herbage species and strains, their incorporation in grass-legume mixtures, the responses of pastures to fertilizer dressings in the long term, pasture management, the use of water by herbage plants and the influence of pastures on soil fertility.

Over the State as a whole, a wide range of climatic and soil conditions has been covered by means of field tests on privately owned properties, and at the Experimental Farm, Kybybolite.

These have brought under examination new species and strains of both legumes and grasses, varying fertilizer dressings including combinations of trace elements with phosphate, and modified systems of pasture management.

1. Top Dressing of Natural Pastures.

A permanent field experiment to determine the effects of equivalent dressings of phosphate (40 lb. P_2O_5 per acre) in the form of superphosphate, basic slag, rock phosphate, and the effect of nitrate of soda (78 lb. per acre) added to the superphosphate, has been maintained continuously since 1925. The effects of each fertilizer on the yield of total herbage, the yield of legumes in the pastures and the stock carrying capacity over 23 years are summarized in Tables 12, pages 103 and 104.

Since 1940, separate flocks of sheep have been grazed on these plots and on two adjoining plots of sown pasture. The carrying capacity, live-weight increases, and wool production of the sheep have been measured each year. The results of these comparisons have shown that the live-weight increase and wool production from individual sheep have been as great on the unfertilized pasture as on the top-dressed pastures and the seeded pastures. The carrying capacity has been lowest, however, on natural pasture where phosphate has not been applied, and has been highest in the case of the seeded pastures.

The yield of natural pasture over this period has varied from 26 to 77 cwt. per acre, with only four seasons below 30 cwt. per acre and eight years below 2 tons per acre.

2. Tests of Pasture Species and Strains.

The introduction and testing of new species and strains of herbage plants has been undertaken continuously since the inception of the Institute. New material is grown first under nursery conditions, then in rows and small plots in the experimental field. As seed supplies of promising material are multiplied field tests are made at appropriate centres in the agricultural areas of the State.

The above work has led directly to the commercial use in South Australia of true *Phalaris tuberosa*, certified perennial strains of rye-grass (*Lolium perenne*), perennial veldt grass (*Ehrharta calycina*), kikuyu grass (*Pennisetum clandestinum*), Dwalganup and Bacchus Marsh subterraneum clover (*Trifolium subterraneum*), barrel medic (*Medicago truncatula*) and Palestine and O'Connors strawberry clover (*Trifolium fragiferum*).

The Gb81 strain of *Phalaris tuberosa* bred at the Institute has been in commercial use since 1943. This strain has better sward-forming properties, a higher drought resistance and better agronomic qualities generally than the commercial phalaris previously grown in South Australia. Its productivity under field trials at the Waite Institute has proved 15 per cent. greater than commercial phalaris and the use of this strain has expanded considerably in recent years.

New material that has shown promise but has not yet reached the commercial stage includes seeding kikuyu grass, rhizomatous lucerne, the Clare subterranean clover, *Trifolium Balansae* and *Medicago solerolii;* the latter two species were introduced through the United States Department of Agriculture in 1940.

Selections of *Triticum-Agropyron* hybrids obtained from the Dominion Experimental Farm, Ottawa, have also shown promise at the Waite Institute.

3. Effect of Superphosphate and Surface Cultivation on a Seeded Pasture.

A pasture of *Phalaris tuberosa* and Dwalganup subterranean clover with a light seeding of Wimmera rye-grass established in 1936 at the Waite Institute has been subjected since 1937 to dressings of 0, 1, 2 and 3 cwt. per acre of superphosphate, with and without cultivation of the pasture in autumn. The land had previously received 10 cwt. per acre of superphosphate. The experiment has been conducted over eleven seasons; cuts for determination of yield, followed by grazing with Merino sheep, have been made during the growing season at intervals of approximately six weeks. For the most part, annual dressings of 1 cwt. per acre (phosphate equivalent 45 per cent.) have proved sufficient following the accumulation of phosphate prior to the commencement of the experiment; in a minority of the seasons higher dressings of 2–3 cwt. per acre have further increased the yield, but taking the period of test as a whole no justification appears evident for increasing the yearly dressing above 1 cwt., once a sufficient accumulation of soil phosphate has accrued.

At no stage has cultivation of the pasture made any difference to its yield or composition. The results of the experiment are set out in Table 13, page 105.

4. Investigation of Pasture Management.

Grazing management trials were commenced in May, 1940, at the Waite Institute and the Experimental Farm, Kybybolite, and were continued to the end of 1945.

In each case an area of 21 acres was seeded to a mixture of subterranean clover, *Phalaris tuberosa* and Wimmera rye-grass. The experiments, which were identical in form at both centres, were designed to compare the effect of continuous as against rotational grazing with and without cutting for hay and feeding back of the conserved herbage during the summer and autumn months,

with two types of sheep, Merino and crossbred (Merino-Romney Marsh) wethers.

The effect of the various treatments was evaluated by comparison of the live-weight gains and wool production of the sheep and by the comparison in 1945 of the productivity and botanical composition of the pastures under each type of management over the previous five-year period at both centres. The quantity of hay produced and the amount fed back to the sheep was also recorded over the full period in both trials.

It was planned to maintain four sheep per acre under all treatments from 1940 onwards. The period of the trial, however, was characterized by two of the four most severe drought years, 1927, 1930, 1940 and 1944, since 1924; and owing to the exceedingly dry conditions in the first year, 1940, it became necessary to reduce the initial stocking rates. Over the full period of the experiment the mean numbers of sheep carried were 3·31 wethers per acre at Kybybolite and 3·50 wethers at the Waite Institute.

Cutting for hay yielded an average annual return of 20 cwt. 48 lb. under continuous grazing and 21 cwt. 109 lb. under rotational grazing at Kybybolite and 18 cwt. 53 lb. under continuous grazing and 15 cwt. 49 lb. under rotational grazing at the Waite Institute.

No significant differences in the total yield of herbage were found in 1945 as between continuous and rotational grazing either with or without the hay cutting treatment. The yield of the sown perennial grass was higher under rotational than under continuous grazing and the hay cutting treatment had no detrimental effect on the yield of this grass. On the other hand, the yield of subterranean clover was greater under continuous than under rotational grazing. Hay cutting further increased the yield of subterranean clover with a resultant lower yield of annual grasses which comprised a higher proportion of the total yield under all treatments generally because the pastures had not established as well as usual when subject to unusually severe conditions of drought in the second year.

The live-weight increases, yield and value of wool, hay cut and fed and the yield composition of the pastures in 1945 are tabulated in Table 14, pages 105–108.

The live-weight per head of the sheep responded only slightly to differences in the conditions of grazing, and the response to hay feeding during summer and autumn varied with the season.

The mean yields of wool per acre per annum of the sheep not fed hay and of those receiving hay were 36 lb. 8 oz. and 37 lb. 5 oz. respectively at Kybybolite, and 44 lb. 10 oz. and 45 lb. 15 oz. respectively at the Waite Institute. At both centres there was a gain of approximately 1 lb. of wool per acre per annum under continuous grazing as compared with rotational grazing.

Under the conditions of this experiment sheep were moved from paddock to paddock each week but there were always sheep in each paddock where the treatment of continuous grazing was imposed.

At both centres no difference appeared as a result of rotational grazing and the results can be summarized for practical guidance to indicate that the management of livestock should be generally along common-sense lines without the imposition of rigidly set schedules because the season cannot be predicted ahead. The aim should be to maintain pastures with a sufficiently good cover but without excess growth. The use of the mower is essential when production

greatly exceeds consumption by livestock and to provide insurance in the form of conserved fodder against the unavoidable years of lower production.

The value of hay feeding in this experiment depended very closely on seasonal conditions. Over the four years of the experiment, 1940–1943, the cost of cutting and conserving hay was by no means met by the additional returns secured; but in the fifth year, 1944, the value of the hay conserved previously converted a debit balance for this practice to a highly profitable one for the full period of five seasons. The value of cutting and feeding back hay appeared to be greater in the case of the crossbred sheep than in the case of the Merinos.

There were two further points of interest, namely, that the health of the sheep was not greatly affected by the changes in management imposed, and that, although the pastures were more productive and appeared more attractive in terms of botanical composition at Kybybolite than at the Waite Institute, the sheep, at all times, made greater gains and yielded heavier weights of wool with a higher value per head at the Waite Institute than at Kybybolite, despite the greater production and apparent superiority of the pasture at the latter centre.

5. The Development of Pastures in Areas of Highest and Most Assured Rainfall.

Climatic studies have emphasized the unused resources of soil moisture in the region of South Australia receiving a mean annual rainfall of 18 inches or more. The soils of this region vary considerably but are, for the most part, deficient in nitrogen and phosphorus, and may be deficient in one or more trace elements.

Until 1945 investigations of the problems posed by these areas were conducted as co-operative projects by the Waite Institute in association with the Council for Scientific and Industrial Research.

About 1940 it became realized that many failures of sown pastures in higher rainfall areas were due to a lack of soil nutrients other than phosphate; and from 1941 onwards an extensive mesh of exploratory experiments was developed to cover the Mount Lofty Ranges, Kangaroo Island, lower Eyre Peninsula and much of the South-East.

Surveys by the Soils Division of C.S.I.R. provided initial classifications of soil types and these were followed by investigations to indicate the nutrient elements most likely to be deficient under field conditions.

Field experiments were conducted on more than thirty properties between 1941 and 1947 and these, in conjunction with pot culture investigations, led to the establishment of molybdenum deficiency in the Mount Lofty Ranges and the Clare district, substantiation of copper deficiency with, in some cases, dual deficiences of copper-molybdenum on Kangaroo Island, deficiences of molybdenum, molybdenum-copper, molybdenum-copper-zinc in the areas to the south of Adelaide, deficiences of copper, zinc and molybdenum on Eyre Peninsula, and of copper-zinc in the upper and lower South-East with, in some cases, copper-zinc-manganese or copper-zinc-molybdenum in the lower South-East.

Among the soils lacking copper and zinc were included the solonized soils carrying low heath and the peat soils near Port MacDonnell and Rendelsham.

Dressings of 2 cwt. of superphosphate per acre per annum for the first three years followed by annual dressings of 1 cwt. per acre per annum, in addi-

tion to any trace elements required, appeared to be necessary for maximum production in most areas of high rainfall.

Associated with the work on artificial fertilizers were trials with new strains of herbage legumes. Among these Bacchus Marsh subterranean clover, Palestine and O'Connors strawberry clover, lucerne, barrel medic, Gb81 phalaris and perennial veldt grass have proved especially successful.

Bacchus Marsh subterranean clover, first introduced to South Australia by the Waite Institute in 1934 and shown to be superior to other early maturing strains from 1935–36 onwards, has proved the most important new herbage plant to be employed in South Australia for many years. The outstanding value of this strain was demonstrated on the Adelaide plains, Kangaroo Island, the upper South-East and Eyre Peninsula between 1941 and 1944.

The combined work on herbage species and strains and artificial fertilizers was undertaken primarily to ensure the success of post-war land development for settlement purposes, which it has undoubtedly done. The investigations had the active support of the Departments of Lands and Agriculture and of many land owners who were intimately concerned with the problems of the areas indicated.

6. Exploratory Investigations of Soil Deficiency by means of Pot Cultures.

Several hundred separate tests have been made on soils which had shown unsatisfactory growth of pasture under conditions of high rainfall.

The majority of these soils were found to respond either to a single element or combinations of elements other than phosphate. Zinc, molybdenum and potash were most frequently found lacking for subterranean clover but five herbage legumes were found to respond to these elements and to copper; the type of response varied considerably with the legumes employed.

Significant interactions were common; the most frequent of these was between potassium and molybdenum.

In no case has a lead from the pot culture investigations been negatived by subsequent field experimental work. In the case of heavy clay flats characterized by lignum and box along the upper Murray River, pot culture investigations revealed both the need for molybdenum and the adverse effects of high salt concentrations near the surface in these soils before these effects were subsequently examined in the field.

7. Investigations of Pasture Improvement in the Mount Lofty Ranges.

Mount Barker subterranean clover has remained the dominant herbage legume in the Mount Lofty Ranges but the value of phalaris, perennial rye-grass and Wimmera rye-grass as associated grasses has been substantiated. Liberal dressings of superphosphate, together with the addition of 1 to 2 oz. of molybdenum trioxide per acre for three seasons have proved necessary to secure full production of these pastures on many soils. Except in rare instances no other elements in addition to phosphorus and molybdenum have given more than slight or doubtful responses on the podsolized soils derived from the ancient sedimentaries of the Mount Lofty Range system.

Amounts as low as $\frac{1}{16}$th oz. per acre of molybdenum salts have given marked responses by legumes, but for maximum yields dressings of 1 oz. per

acre have been recommended. Responses to molybdenum application were poor where the phosphate level of the soil was low and on newly cleared areas heavy phosphate dressings were required.

In species and strain trials at Waitpinga, cocksfoot and perennial rye-grass outyielded phalaris and perennial veldt grass under light grazing conditions. Subterranean clover has been the outstanding pioneer legume; a mixture of the Bacchus Marsh, Mount Barker, and Tallarook strains was suggested by the marked variation in their relative yields from season to season. In 1946 the winter production of the recently named Clare strain was notable.

At Mount Compass the early mid-season and mid-season strains have been more productive than Tallarook. Clover yields were increased by the inclusion of perennial rye-grass in the mixture, probably due to greater protection of seedlings.

8. Grassland Investigations, South-East.

These may be grouped under two heads:

(a) Co-operative investigations of the C.S.I.R. which terminated in 1944.
(b) Investigations in conjunction with the Australian Wool Board from 1944 onwards.

(*a*) *Investigations of soil deficiencies, 1943–44.* The results of this work were the outcome of experiments commenced for the most part in 1941 and referred to in the previous report of the Waite Institute.

The following soil types were investigated:

(1) Terra rossa at Mount Benson.
(2) Rendzina at Naracoorte.
(3) A drained calcareous soil at Rendelsham.
(4) Drained peat soils at Rendelsham and Eight Mile Creek, Port MacDonnell.
(5) Solonized soils carrying low heath, Wood's Well.
(6) Heath podsol at Wattle Range.

At Mount Benson significant responses to copper were obtained and evidence was recorded that zinc and potash were likely also to be required.

The soil type posseses certain affinities with the solonized soils of the Wood's Well area and the upper South-East generally. Subterranean clover proved to be the most vigorous legume, but *Medicago* species also grow satisfactorily on this soil, the reaction of which was neutral.

Evidence was gained that under certain conditions the high salt content of the rendzina soils could prove a limiting factor. Strawberry clover, phalaris, and Wimmera rye-grass appeared to grow well on these soils, and indications were obtained that both copper and zinc were likely to be needed.

On a drained calcareous soil at Rendelsham black medic and strawberry clover proved to be the dominant legumes where phosphate was applied. Growth was poor under limited phosphate and was gradually improved up to dressings of 8 cwt. superphosphate per acre. The legumes were improved by a mixture of trace elements including copper, zinc, and manganese, but the effects of the individual elements concerned were not separated. This land was found capable of high production with proper methods and deserves further attention.

On drained peat soils at Rendelsham and Eight Mile Creek applications of 7 lb. copper sulphate and 7 lb. zinc sulphate with 2 cwt. superphosphate per acre resulted in much more growth than where no copper and zinc were applied. With the copper and zinc 4 cwt. superphosphate per acre gave considerably greater yields than where only 2 cwt. was used.

In one trial at Eight Mile Creek, growth was further improved by the use of 7 lb. manganese sulphate per acre. Certified perennial rye-grass, cocksfoot and white clover, phalaris, lucerne, black medic, and barrel medic were the most satisfactory herbage species at this centre.

On solonized soils carrying low heath on the property of Dr. M. Schneider, Wood's Well, County Cardwell, experiments were commenced in 1941 to determine the fertilizers required for the effective development of these upper South-East soils, large areas of which are still Crown lands.

Good pastures were developed with a liberal dressing of superphosphate with copper sulphate and zinc sulphate, all of which were found necessary for maximum growth.

A marked improvement in lucerne was obtained with a dressing of 9 lb. copper sulphate per acre applied either with previous crops or directly with the lucerne. This benefit persisted strongly for four years.

Compared with other levels of phosphate, dressings of 2 cwt. superphosphate per acre in each of the first three years proved most satisfactory. Poor growth may result from similar dressings in the initial year, but this is likely to improve subsequently as the phosphate status is raised

Bacchus Marsh subterranean clover, lucerne, *Phalaris tuberosa* perennial veldt grass and evening primrose proved to be the most satisfactory herbage plants. Excellent growth of mixed pastures containing these species was obtained where dressings of 2 cwt. superphosphate were applied each year for the first three years, together with 7 lb. copper sulphate and 7 lb. zinc sulphate per acre at seeding. Total yields of 30 cwt. dry matter per acre were commonly obtained and in some cases yields of above 50 cwt. dry matter per acre were recorded. No significant responses were obtained with nutrients other than phosphate, copper, and zinc when applied to relatively small field plots.

On the heath podsol at Wattle Range, subterranean clover of the Mount Barker type proved to be the dominant legume. Growth, however, was disappointing even when liberal phosphate and all additional known nutrients were applied.

Although fairly good yields were obtained in some cases, many of the results appeared to be conflicting, and it became obvious that the soil required further and intensive study.

(*b*) *Investigations in conjunction with the Australian Wool Board, 1944–47.* The programme of work conducted by the Institute under a grant from the Australian Wool Board has comprised an ecological survey of the grasslands and an investigation into problems of pasture establishment and development on particular soil types.

(1) *Grassland Survey.*

An ecological survey of the grasslands of the South-East was conducted over the three-year period of 1945–47, inclusive, and is being continued. The Levy point quadrat technique was chosen for the quantitative analysis of

pasture swards. In the first instance the reliability of this method for large scale survey work was tested and the results were found to be highly satisfactory. From the botanical analyses, the grasslands can be classified into pasture types according to the dominant grass and legume species considered in relation to the ecological factors of soil, climate, and management. The pasture types are not entirely stable, being affected by such influences as manuring, cultural practices, grazing, insect pests, and seasonal fluctuations. However, the greater stability of the pastures dominated by perennial species is clearly demonstrated from the results of the survey.

The survey is also proving valuable in assessing major successional trends resulting from the various field husbandry practices. Problems in pasture establishment, development, or maintenance have been more clearly defined and opportunity has been provided for the collection of information derived from the practical experience of landholders contacted during the course of the survey. It is hoped to extend this type of survey to other parts of the State, so that a sound basis for research will be available throughout the better pastoral districts generally.

(2) *Field experiments.*

(*a*) *Investigations of sown pastures on the rendzinas.* A series of fertilizer trials designed to investigate the mineral requirements of the rendzina soils in the South-East has been established. Widespread responses of strawberry clover to applications of zinc in addition to superphosphate have been obtained. Indications have also been noted of a probable manganese deficiency.

Trials with herbage species have demonstrated that several legumes, including *Medicago lupulina* (black medic), *M. truncatula* (barrel medic), *M. solerolii,* and *M. hispida sardoa,* may be grown satisfactorily on these soils under favourable drainage conditions, but fail where flooding occurs. Under these latter conditions *Trifolium resupinatum* (annual strawberry clover) has proved successful. The above are largely subsidiary legumes, as the most important herbage legume on these soils is unquestionably the perennial *Trifolium fragiferum* (strawberry clover). This is adapted to excessively wet conditions in winter and will survive where most annual legumes have failed. The two strains, Palestine and O'Connors, have proved successful as the basis of pasture mixtures and are superior to many other strains which have been tested.

(*b*) *Investigations of sown pastures on the heathlands.* The nutrient requirements of the heathland soils and the most suitable pasture species for their development have been studied by a series of fertilizer and species trials. In addition to phosphate, responses have been obtained to potash, copper, and zinc, and the value of several legumes, including subterranean clover (Bacchus Marsh and Mount Barker strains), strawberry clover, and *Trifolium Balansae* has been demonstrated.

The failure of these legumes during the initial years of development, even when adequate superphosphate and other essential minerals have been applied, suggests that another factor inhibits clover growth. Field observations and laboratory results give support to the suggestion that this factor primarily affects nodulation and rhizobial functioning. Further investigations are in progress.

9. Development of Seeded Pastures on Irrigable Clay Flats.

Investigations have been conducted on heavy clay flats formerly under box and lignum within a lift of 30 feet from the River Murray in the Renmark district since 1944.

These have demonstrated that a high content of total soluble salts in the surface soil frequently inhibits the successful development of pasture on such flats.

The two most successful herbage species were Rhodes grass and lucerne. Both are capable of high salt tolerance, persisting at concentrations above 0·5 per cent. provided irrigations are sufficiently frequent and surface cover, which tends to be provided rapidly by Rhodes grass, is maintained. Surface ridging and the frequent use of some excess water to flush the surface tend to accelerate removal of surface salt.

In addition to Rhodes grass and lucerne, perennial rye-grass, phalaris, and barrel medic grew satisfactorily, but could only be regarded as associates of the two main pioneer species.

Cocksfoot, prairie grass, paspalum, red clover, white clover, strawberry clover, black medic, and subterranean clover did not succeed, although both white clover and subterranean clover may prove productive as the salt content becomes further reduced. Kikuyu grass is likely also to prove a useful species as development proceeds.

The incorporation of gypsum with the surface soil prior to seeding did not improve the growth of the pasture. The nitrogen status of the soil prior to the establishment of herbage legumes such as lucerne and barrel medic was insufficiently high for the production of normal cereal crops.

Applications of copper, zinc, and molybdenum over and above a basal dressing of 2 cwt. superphosphate per acre per annum improved the mean yield of the pasture mixtures from 63·05 cwt. to 89·31 cwt., and of lucerne from 93·68 cwt. to 150·04 cwt. over three seasons. The application of molybdenum resulted in significant improvement throughout. This had been suggested from earlier pot culture tests. The addition of copper and zinc improved the growth of lucerne and phalaris: in the case of lucerne, copper-zinc-molybdenum produced a lower yield than molybdenum only, while in the case of Rhodes grass, copper-zinc-molybdenum produced a lower yield than copper-zinc only. The negative interaction Mo×CuZn was highly significant with these two species, and has also been recorded with lucerne in pot cultures.

Cover crops and conditioning crops were found to be unproductive and of no value in the improvement programme. Exploitative cropping of any kind is likely to be detrimental. The key to the development of these flats under irrigated pasture lies in the use of lucerne as the initial herbage legume, together with associated light seedings of Rhodes grass, the reduction of surface salt by frequent moderate watering, the application of molybdenum with liberal dressings of superphosphate in the earlier years, followed by additions of copper and zinc as other herbage species enter the pasture, and the maintenance of surface cover throughout the programme of development.

10. Pasture Investigations in Low Rainfall Cereal-growing Areas.

Cropping with wheat in narrow rotations has led, in many of the low rainfall districts, to a decline in soil fertility and to wind and water erosion of the soils. It is believed that the solution of these problems depends on the

improvement and greater use of pasture, and investigations have been continued in an attempt to find suitable species and methods of establishment for these conditions.

The investigations have been carried out mainly on the farm of Mr. R. L. Davidson at Pallamana, a centre fifty miles east of Adelaide, where the mean annual rainfall over the period 1938–47 was 14·41 inches. The soils here conform generally to the mallee (brown solonized) type. A rotation experiment involving four-course and eight-course rotations of cereal crops and pastures commenced in 1939, had to be abandoned at the end of 1944 because of difficulty in maintaining large scale work in the region at that time. There were indications of improved yields of wheat under wide rotations. Pastures seeded to a mixture of lucerne, barrel medic, perennial veldt grass, and Wimmera rye-grass were successfully established under a wide range of seasonal and cultural conditions. Pastures established on wheat stubble or with a cover crop of wheat were as productive as those sown on fallow. Lucerne was the outstanding species, but barrel medic and Wimmera rye-grass also performed well. In terms of total yield of dry herbage, however, the sown pastures were not greatly superior to the natural pastures.

In 1946 a series of pasture experiments was laid down at a number of low rainfall centres, including Pallamana, to compare the persistence and productivity of different perennial grasses. The species tested were perennial veldt grass, *Phalaris tuberosa*, crested wheat grass, and wallaby grass. Evidence gained from these seedings indicated that Gb81 phalaris is capable of persisting under low rainfall conditions; that perennial veldt grass is well adapted to the lighter soils, but does not succeed on the heavier soil types; that crested wheat grass, is highly drought resistant and, despite its poor winter production, is worthy of further investigation, particularly in the northern agricultural areas of the State.

Examination by the pot culture technique has indicated the possibility of zinc and potash deficiencies in these soils.

11. Investigations of Shrub Pastures.

Investigations relating to pasture regeneration and management in the arid pastoral country of South Australia were begun in 1937 under the terms of the Ranson Mortlock Trust. The work, which is centred at Yudnapinna Station, 250 miles north of Adelaide, has included a field study of regeneration in protected and unprotected quadrats, combined with a more detailed study of the climatic and soil factors affecting the germination and establishment of the principal species. The effects of different rates of stocking and periods of grazing on the yield and composition of bluebush pasture are also being examined.

Within the enclosures protected from stock and rabbits a slow but steady regeneration of saltbush and bluebush has taken place where sufficient "mother" plants remained to provide seed supplies; but on one enclosure, which was completely denuded of perennial shrubs at the beginning of the experiment, no improvement has occurred. Several conditions are necessary to ensure effective regeneration of saltbush and bluebush, including seed supply, suitable seed-bed conditions, favourable conditions of rainfall and temperature, and protection of the young plants from grazing. Only rarely are these conditions fulfilled, and consequently regeneration of denuded areas is a slow process. Laboratory

tests have shown that saltbush is fairly specific in its requirements of temperature and moisture for germination, and that temperatures above 20° C. (68° F.) tend to inhibit germination. Bluebush, however, germinates successfully at temperatures rising to 30° C. (86° F.). These results have an important application to the regeneration of the two species in the field.

Data from the grazing experiment have indicated the marked influence of seasonal conditions in determining the amount and composition of available herbage, and have emphasised, too, the value of the perennial shrubs, the production from which does not fluctuate as widely as that from the annual species. The outstanding effect of the heavier stocking rates has been to increase the density of bluebush at the expense of herbage and grass species. It has been found that rates of stocking with sheep greatly in excess of those ordinarily carried on these pastures can be maintained, provided the paddocks are small.

As a result of the detailed observations afforded by the grazing experiment, it is possible to interpret the ecological trends that have occurred over large areas of shrub pastures in South Australia.

4. WEEDS AND WEED CONTROL.

Investigations relating to the control of the one-leaved Cape tulip (*Homeria collina*) and two-leaved Cape tulip (*H. miniata*) were resumed in 1947, when a survey of the whole infestation in southern Australia was commenced. The aims of the survey were to assess the nature and importance of the problem, to determine the environmental limits to the distributions of the plants, and to make observations on the behaviour of the species under a variety of habitat conditions.

The weeds extend over approximately 130,000 acres in the better rainfall districts of South Australia, Western Australia, Victoria, and New South Wales. The distribution of *H. collina* extends slightly beyond the line denoting a seven months' growing season, while *H. miniata* is persistent under a six months' season; both are tolerant of water logging for several weeks in the winter. The soils of areas infested with one-leaved Cape tulip are in general light in texture, acid in reaction, and deficient in phosphorus, nitrogen, and frequently in other elements. Of eleven soils tested in 1947 nine showed responses to the application of trace elements and potash; similar responses have been obtained on soils from many other tulip infested areas. The distribution of the other species with respect to soils differs in that it extends to alkaline soils of heavier texture.

Cape tulip infestation is usually associated with poor vegetative cover, due in part to the low fertility status of the soils and to associated overgrazing. Pastures comprising vigorous grass and legume species present a barrier to weed invasion and, by increasing the carrying capacity of a property, justify the use of more expensive control measures for smaller non-arable areas. The investigation of factors affecting the establishment and maintenance of sown pastures therefore is an important aspect of the work.

Mechanical control methods are effective if used correctly; the critical factor is the stage of development of the tulip plant. Such measures must be applied when the food reserves of the plant are at a minimum, that is when the

reserves of the parent corm are almost exhausted and the development of the new corm has just commenced. This vulnerable period, which precedes flowering by several weeks, extends for three or four weeks and usually commences from mid-June to late July. If applied too early, mechanical methods do not prevent further growth and subsequent development of new corms; they are not effective if the formation of new corms has been completed.

Irregularity in the stage of corm development and the presence of dormant corms in the soil necessitate a three-year control programme. During this period, returns may be obtained from the area by the use of late-sown cereals or summer forage crops.

The methods outlined above are applicable to the greater part of the infestation in Australia. There remains an important area of non-arable land for which other control measures must be found. Preliminary tests, using a number of growth-inhibiting substances, applied singly and in combination with other compounds, have been made under pot culture conditions to provide a basis for planning field experiments. Promising results have been obtained with 2, 4 dichlorphenoxyacetic acid (2, 4, D.) and related substances, and with dinitrophenol compounds. The effects of soil nutrient and moisture status, atmospheric and light conditions, growth stage of the plant, and addition of other substances to the spray solution require further investigation.

5. BOTANICAL SERVICE.

The routine work of the botanical section is undertaken by a systematic botanist who is responsible for the accurate determination of plants. This necessitates the maintenance of a herbarium in which all specimens of value are named, mounted, protected from insect attack, and indexed. This herbarium now contains more than 5,800 specimens and includes native species, pasture plants and weeds of special interest to the Institute, and some introduced trees and shrubs.

An advisory service is supplied to the Minister of Agriculture; the Weeds Adviser of the Department of Agriculture is informed of new weeds, or new occurrences of weeds previously reported, and such advice is reciprocated. This service is also available to the Minister of Afforestation and to private individuals. Information concerning weeds, drug plants, herbage plants, and tree planting is made available on enquiry. The experience gained from the establishment and maintenance of the Waite Institute arboretum has proved of much value. Approximately 1,260 plants were determined and reported on during the period 1943–47.

Alarm was occasioned by the appearance in this State of skeleton weed (*Chondrilla juncea*) at Parilla in March, 1947, and subsequently at other centres. Another serious weed, Noogoora burr (*Xanthium pungens*), was received in August, 1947, from Ardrossan; this species was presumably introduced through the agency of floodwaters. The latter, fortunately, was only local and has been suppressed. Russian knapweed (*Centaurea repens*) is now widespread in this State, including Kangaroo Island, and is to be regarded as potentially serious on account of its persistent creeping root system.

Other weeds worthy of note include the perennial Lincoln weed (*Diplotaxis tenuifolia*), innocent weed (*Cenchrus tribuloides*), Ward's weed (*Carich-*

tera annua), perennial ragweed (*Ambrosia psilostachya*) and long fruited wild turnip (*Brassica Tournefortii*).

The eradication of certain types of troublesome weeds has been much simplified since the introduction on the market in the last few years of the hormone type weed killers. Effective control of a number of perennial weeds, such as bindweed (*Convolvulus arvensis*), can now be readily achieved. These weedicides are superior to the substances employed earlier in that they are non-inflammable, non-poisonous to humans or farm animals, may be simply applied, are conveyed to the growing points within the plant, resulting in complete mortality where the plant is susceptible, are highly selective and do not render the soil toxic.

6. GUAYULE.

Investigations of the Mexican rubber plant, guayule (*Parthenium argentatum* Gray), in South Australia were initiated in July, 1942, as a joint project of the Council for Scientific and Industrial Research, and the Waite Agricultural Research Institute. The earliest agronomic trials were on an extensive scale, as outlined in the previous report. In 1943, however, partly because of difficulties in seed germination and seedling establishment, and partly because of the improvement in the rubber position, the project became purely investigational.

The factors governing seed germination, nursery production of seedlings, and seedling establishment in the field were determined. The detailed investigations into seedling treatment prior to transplanting, showed that topping was the most important single factor covering seedling establishment. It was shown that cutting back completely to the stem collar gave almost 100 per cent. establishment, while the retention of even small amounts of mature leaf reduced establishment considerably.

The climatic and soil conditions affecting the growth and development of guayule were also defined. Once field establishment is achieved the drought resistance of the plant is very high. Effective establishment depends on the coincidence of relatively warm temperatures (higher than 60° F.) with adequate soil moisture. In South Australia, under natural conditions, the required combination of moisture and temperature is only to be anticipated for restricted periods in the spring and early summer months in the assured rainfall districts. Even here the expectancies of suitable conditions for a period of eight weeks or more is for the most part less than 60 per cent. of all seasons. Suitable climatic conditions for the satisfactory establishment and development of guayule in South Australia are therefore, in the absence of irrigation, very restricted. Even where climatic conditions are suitable, satisfactory growth is only made on light and medium-textured soils.

A large range of field plantings, both under irrigation and in the areas of most assured rainfall have been established, so that the course of rubber formation in the plant can be followed under a wide range of conditions. With the establishment of these plantings, and after completion of the investigation of the more important ecological aspects in 1945, the project has become entirely a chemical study of the rate of growth and rubber content of the plants in these areas. This subsequent work is reported as an activity of the Council for Scientific and Industrial Research on pages 67 and 68.

Agricultural Chemistry

1. IMPROVEMENTS IN LABORATORY TECHNIQUE.

Chemical methods for the examination of soils and plant materials have continued to receive attention. Most of the methods already developed and standardized have continued to give satisfactory results in routine use on a wide variety of soils. The monograph* containing these methods has been favourably received and a photo-offset edition has been published in America by Interscience Publishers Inc. It has also been necessary to make further printings of the Australian edition.

Methods for the fractionation of phosphate compounds in soils have been examined and a suitable procedure chosen for the study of phosphate reversion and availability in South Australian soils (see below). A considerable amount of work has been done on colorimetric methods of analysis. A simple photo-electric colorimeter has been constructed and this instrument has enabled measurements of colour intensity of solutions to be made with a precision of better than 0·2 per cent. The use of this instrument has greatly increased the accuracy attainable in colorimetric analysis and has eliminated the uncertainty and fatigue associated with the visual comparison of colour intensity. A satisfactory method has been developed for the determination of the small amounts of molybdenum occurring in plants. After extraction of the molybdenum from acid solution by means of cupferron and chloroform, it is converted into its complex with dithiol. When this is extracted into amyl acetate it gives an intensely green solution, very suitable for its quantitative determination. Amounts of molybdenum as little as 0·1 microgram can be readily determined.

2. MINERAL DEFICIENCIES.

The extension of the areas sown to flax in South Australia, to meet war-time requirements, showed that on certain soils this crop failed because of a deficiency of available zinc in the soil. Experiments were carried out, in association with the Department of Plant Pathology, to investigate the availability of zinc in relation to the flax crop. Zinc deficiency was most serious on rendzinas and black earths occurring in the zone of the red brown earths. It was restricted to the dark coloured soils and was never found on soils of reddish colour. Flax collected from the control plots in the field trial at Saddleworth showed a relatively low amount of zinc in the dry matter. The application of zinc sulphate in the fertilizer mixture prevented the "dieback" of the young flax plants and increased the proportion of zinc in the plants. Because zinc calcine (the material produced in the roasting of zinc ores before refining) also showed value as a source of zinc in field experiments at Saddleworth and O'Halloran Hill, its use was further examined in a field experiment at the Waite Institute in 1944. This experiment was designed to determine the relative uptake of zinc by flax from equivalent amounts of zinc applied as the sulphate ($ZnSO_4$) or calcine (ZnO). Analysis of the flax crop grown on this soil type (Urrbrae loam), which is not subject to any known deficiency of the trace elements, showed that zinc calcine was almost as effective as zinc sulphate

* "Soil and Plant Analysis," by C. S. Piper, Adelaide, 1942.

in providing a source of readily available zinc. Because zinc calcine is only a fraction of the cost of the sulphate it may prove of considerable value as a cheap source of agricultural zinc.

Further water culture experiments were carried out, particularly on the influence of manganese and copper on plant growth. In one experiment the influence of the relative amounts of iron and manganese in the nutrient solution was investigated. It was found that the absolute amounts of these two elements, rather than their ratio, was the more important factor controlling the growth of oats. In the absence of manganese, clearly defined manganese deficiency lesions were found on the leaves of all plants, even in those cultures devoid of iron. At low iron concentrations the amount of this element was the prime factor limiting growth; stunted growth and a general chlorosis were the most obvious expressions of this deficiency. At low iron concentrations, manganese deficiency represented a secondary deficiency. Only when iron was no longer a limiting factor did the lesions due to manganese deficiency become severe and the prime cause of restricted growth.

Another experiment was carried out to compare the relative requirements of rye and oats for copper. When these plants were grown in nutrient solutions with restricted supplies of copper and under precisely controlled conditions, the amount of growth made by each plant was directly proportional to the amount of copper at its disposal. For each microgram of copper supplied each species produced approximately 1 g. of dry matter. In a copper-free nutrient solution, rye made more growth than oats but this was due to the extra amount of copper contained in the rye seed. The experiment showed that rye needed as much copper for healthy growth as did oats and supported earlier observations that the better growth of rye on certain deficient soils was associated with its greater capacity to absorb copper from the soil rather than a lower requirement of this element.

To assist the Division of Animal Health and Production of C.S.I.R. in their investigations on toxaemic jaundice, a pot experiment was carried out in 1945 to compare the relative amounts of copper taken up by three species of plants from two different soils. One soil was from the Division's field station at Barooga, New South Wales, where grazing sheep frequently accumulate excessive amounts of copper in their livers. The other soil used for comparison was Urrbrae loam. Of three species of pasture plants tested (*Medicago denticulata, Erodium cygnorum* and *Hordeum leporinum*) only *H. leporinum* showed a significantly higher amount of copper in the dry matter when growing on Barooga soil than when grown on Urrbrae loam. Even then the difference was not great. An attempt was made to fractionate the copper in the green plant into "readily extractable" and "fixed" fractions and here again there were no significant differences in the distribution of copper between these two fractions for the plants growing on the two soils. It was apparent that the amount of copper in the herbage grown on Barooga soil was not in itself sufficient to account for excessive storage by animals grazing on it.

Other investigations with trace elements have included a study of a microbiological method for the determination of the molybdenum status of soils. The growth and nitrifying capacity of *Azotobacter* are directly related to the amounts of molybdenum available to it. Some of the factors affecting its growth in different nutrient media, in the presence of added soil, were studied, but the method was not found to be of sufficient value in assessing the amount of readily available molybdenum to warrant the large amount of analytical work involved.

3. THE AVAILABILITY OF PHOSPHORUS IN SOUTH AUSTRALIAN SOILS.

During the five years under review laboratory, pot and field experiments have been carried out to investigate the forms of phosphorus occurring in soils, the availability of the different phosphorus compounds and the response to applied superphosphate in soils of different phosphate status. Field experiments at the Waite Institute have been carried out in co-operation with the Department of Agronomy, that at Roseworthy Agricultural College with the co-operation of the College authorities and those at other country centres with the co-operation of the South Australian Department of Agriculture.

Only a small proportion of the superphosphate applied with a cereal crop is taken up by that crop. In many cases as little as 10–25 per cent. is absorbed; it seldom reaches as much as 40–50 per cent. The remainder of the applied superphosphate reacts with the soil and is reverted to less soluble forms. By means of field and pot experiments with many South Australian soils, it was found that the large responses in growth and yield, which were characteristic of applications of superphosphate in the initial years of cultivation and fertilization, were no longer being obtained. A cumulative residual effect was becoming evident. Following repeated fertilization of preceding crops, responses became smaller and, by the time quantities of superphosphate approaching 1 ton per acre had been applied with previous crops, the phosphate status of the soil had been built up to such an extent that little or no response was obtained with current applications of superphosphate. When such a stage has been reached the economic application of superphosphate should correspond to that amount sufficient to maintain fertility. Further field experiments are now in progress to obtain more information on this aspect.

(1) *Fractionation of Soil Phosphorus.*

A simplification of Ghani's method for the fractionation of soil phosphorus gave the most promising results and was used extensively in this investigation. The behaviour of a number of synthetic phosphate compounds and natural phosphatic minerals indicated that this method could be used to fractionate the phosphorus compounds in the soil as follows:

(a) Extraction by 2·5 per cent. acetic acid and 1 per cent. 8-hydroxyquinoline: principally calcium, magnesium and manganese phosphates.

(b) Subsequent extraction by 0·1N sodium hydroxide:

(i) Inorganic fraction—
basic iron and aluminium phosphates,
adsorbed phosphate,
titanium phosphate.

(ii) Organic fraction—

(c) Residue—not extractable by (a) or (b):
crystal lattice phosphorus,
some apatites and other resistant phosphatic minerals.

(2) *Fixation of Phosphates.*

Determinations of the phosphate adsorption capacity of a number of soils and common soil minerals showed that the alumino-silicate clay minerals kaolinite, montmorillonite and illite and the sesquioxide minerals limonite, goethite

and diaspore all had different and distinctive pH : phosphate adsorption relationships. The pH : phosphate adsorption curves for soils did not correspond to any of the curves for pure minerals but could represent a combination of two or more mineral constituents. Organic matter also influenced the phosphate adsorption capacity and this was apparent in soils taken from different parts of the Waite Institute.

(3) *Residual Phosphorus.*

Examination of cultivated soils from long term field experiments showed that all of the residual phosphorus (derived from previous applications of superphosphate) was extractable by 2·5 per cent. acetic acid and 8-hydroxy-quinoline, followed by 0·1N sodium hydroxide. Practically all of the residual phosphorus remained in the inorganic form; very little, if any, change was found in the organic phosphorus as the result of applications of superphosphate.

In non-cultivated soils (soils under pasture) top dressing with superphosphate led to an increase in the organic phosphorus fraction. In addition some of the applied phosphorus appeared to have entered a form not extractable by the above extractants. The increase in the organic phosphorus did not appear to be directly proportional to the amount of phosphate applied but tended to approach a constant amount, irrespective of the nature and amount of phosphorus applied. When rock phosphate and basic slag were used as fertilizers a larger proportion of the applied phosphate was retained in an acetic acid soluble form than when superphosphate was used.

The reaction of the soil played an important part in determining the distribution of phosphate between the two inorganic extractable fractions of the soil phosphorus. In alkaline soils relatively more phosphate was retained as calcium and magnesium phosphates. In acid soils relatively more phosphate was retained as basic iron and aluminium phosphates or by adsorption.

In cultivated soils the various phosphorus fractions were distributed uniformly throughout the ploughed depth and there was little penetration of phosphorus beyond this depth. In uncultivated soils the major proportion of the applied phosphorus was retained in the surface inch of soil and very little penetration was recorded below 4–6 inches. Penetration appeared to take place most readily in the organic form.

(4) *Native Phosphorus.*

Partial fractionation of the soil phosphorus in a series of red brown earths and solonized brown (mallee) soils indicated that the fraction insoluble in the acetic acid : 8-hydroxy-quinoline and the sodium hydroxide solutions made up over 50 per cent. of the total native phosphorus in both groups of soils. The next largest individual fraction was the organic phosphorus, accounting for nearly 30 per cent. of the total phosphorus in these soils. Only 15 per cent. of the total phosphorus was present as inorganic extractable phosphorus in the red brown earths and 19 per cent. in the solonized brown soils.

(5). *Relationship between Soil Phosphorus and Plant Phosphorus.*

In pot experiments with Urrbrae loam (pH 5·6–6·1) wheat plants derived approximately 60 per cent. of their phosphorus from that fraction of soil phosphorus soluble in 2·5 per cent. acetic acid and 8-hydroxy-quinoline and 30 per cent. from the inorganic fraction soluble in 0·1N sodium hydroxide. Very

little use was made of the organic fraction of soil phosphorus. In field experiments on the same soil the percentage phosphorus in the crop was directly correlated with the acetic acid soluble, the inorganic alkali soluble and the sum of these two fractions of soil phosphorus. In pot experiments on a wider range of soils both the phosphorus content of the plant and the total phosphorus uptake showed a good correlation with the total inorganic extractable phosphorus in the soil.

Pot and field experiments confirmed the value of the method of partial fractionation of soil phosphorus as a fertility index. For neutral to slightly acid red brown earth soils either the acetic acid soluble, the inorganic alkali soluble or the sum of these two fractions may be used as an index of fertility. On Waite Institute soils showing phosphorus to the extent of less than 150 p.p.m. in these two fractions appreciable responses to superphosphate were obtainable. On soils with 150–200 p.p.m. small responses were obtainable while soils with more than 200 p.p.m. of total extractable inorganic phosphorus gave no response to applied superphosphate. The corresponding figures for the two separate fractions were:

	Acetic acid soluble fraction.	Inorganic alkali soluble fraction.
Appreciable response	<40	<100
Small response	40–60	100–150
No response	>60	>150

For alkaline soils of the types examined, the inorganic alkali soluble fraction appeared to be the most suitable index. Responses to superphosphate were obtained on all soils showing less than 60 p.p.m.

4. MISCELLANEOUS.

A detailed study of kieselguhr filter aids was undertaken in 1943. This project was carried out at the request of the Scientific Liaison Bureau to assist in meeting the Australian war-time requirements of this material. The addition of properly processed kieselguhr to turbid water before filtration enables a clear filtrate to be obtained easily and quickly. The material was required in large quantities by the Army for the filtration of drinking water in mobile filter units. Specifications of a suitable product were required so that the quality of locally processed diatomaceous earth could be controlled. It was found that many Australian deposits of kieselguhr consisted of species of diatoms known to be of inferior types for the production of high grade filter aids. However, if properly processed, they were capable of yielding a satisfactory product. Particle size and filtration rates were investigated and assistance was given in drawing up a performance specification.

5. INVESTIGATIONS ON PLANT VIRUSES.

Long range fundamental investigations into the nature of plant viruses have been continued but at the same time emphasis has been placed on investigations of the metabolic changes produced in plants as a result of infection by the viruses being studied.

1. Tobacco Mosaic.

(1) *Nitrogen and Phosphorus Metabolism of Virus-affected Plants.*

The relative growth rate of leaf tissue of tobacco plants infected with tobacco mosaic virus was found to be lower than that of healthy control plants. The presence of the virus also caused considerable differences in the concentration and amounts of protein nitrogen and phosphorus.

Protein Nitrogen expressed as a percentage of the dry weight decreased with age of plant in both healthy and infected plants but the rate of decrease was less for infected plants than for healthy ones. The greater concentration of protein nitrogen in mosaic infected plants was more than offset by the slower growth rate with the result that the total amount of protein nitrogen was lower in infected than in healthy plants.

Protein phosphorus (as per cent. dry weight) decreased by about 40 per cent. in healthy plants over a 40-day period, but the concentration of protein phosphorus in the virus affected plants did not change significantly. The total amount of protein phosphorus increased to a maximum in both healthy and infected plants after about 17 days. Thereafter the amount in the healthy plants remained sensibly constant but the total continued to increase in the infected plants. Both the concentration and total amount of protein phosphorus was, therefore, higher in the infected plants than in the healthy ones.

The nitrogen-phosphorus ratio of the protein in the healthy leaves fell from an initial value of 112 to 69 after 40 days, whereas that of the infected plants was consistently lower and reached a value of 54 after 40 days.

The virus content of the infected leaves as determined by the primary lesion method revealed that the virus formed an increasingly large proportion of the total protein of older leaves as infection proceeded, but constituted a roughly constant proportion of the younger leaves.

The virus content of the leaves as determined by an independent chemical method gave values of the same order as those obtained by the primary lesion method. However, the values calculated from the differences in the nitrogen-phosphorus ratios, on the assumption that these are due solely to the presence of virus nucleo-protein in the infected leaves, were in most instances higher than those obtained by the other two methods. Taking the plants as a whole the "ratio" method gave values about three times larger than those obtained by the infectivity (primary lesion) method. When the leaves were separated into younger and older it was found that the ratio method gave values for the younger leaves which were four times that of the infectivity method while for the older leaves the difference varied with the harvest (i.e. length of infection).

The differences may be due to one or more of a number of causes and their further study may throw considerable light on the whole problem being investigated.

The whole of the above section refers to plants grown with adequate nitrogen. A parallel lot of plants grown with an inadequate supply of nitrogen, so that virus and plant would compete for it, gave results which were in the main similar to those described above but there were important differences.

(2) *Whole Leaf Protein of Healthy and Infected Leaves Compared.*

The partial amino-acid composition of normal protein present in healthy tobacco leaves was determined and compared with that of leaves infected with tobacco mosaic virus. The relatively small differences observed could be

accounted for on the basis of a mixture of healthy protein and virus nucleoprotein which differ widely in some respects.

However, one striking difference was noticed—long infection had a marked effect on some physical properties of the non-viral protein in infected leaves.

(3) *Serological Work.*

Antisera to tobacco mosaic virus, made by intravenous injection of solutions of pure virus into rabbits, reacted normally with solutions of pure, active virus as antigen, giving both a constant antigen optimum and a constant antibody optimum. The possibility of using the optimum proportions method to estimate the amount of virus in solutions was investigated and comparisons were made with the end titre method and the primary lesion (infectivity) method.

The work has shown that the optimum proportions (constant antigen optimum ratio) method as used in serological estimations of proteins is capable of being usefully applied to the estimation of tobacco mosaic virus both in pure solution and in crude juice.

Taking as the standard the known weight of pure virus in a series of solutions, the percentage error of this method is of the order of 17 as compared with 27 per cent. for the end titre method and 8 per cent. for the primary lesion method.

(4) *Longevity Trials.*

Solutions and suspensions made from mosaic virus harvested in July, 1935, continue to be tested at intervals. The infectivity of all except one has fallen off during the period under review. One suspension of clean white virus in buffer at pH 4·0 is just as infective as it was when first tested in July and August, 1935. The sample stored at pH 7 is now only about half as infective as it was when prepared.

2. Tomato Spotted Wilt (T.S.W.).

(1) *Strains.*

(a) *Separation of four strains of T.S.W.* In order to maintain a steady supply of T.S.W. virus for experimental work we have for many years carried on serial transfers by mechanical inoculation of healthy plants with the juice expressed from an older batch of infected plants. The virus we were propagating had every appearance of being a single pure line.

This state of affairs continued until in 1941 our supply of T.S.W. virus became contaminated with tobacco mosaic virus (for which all inocula are regularly tested) and a new "line" was started by using fresh source material. After a few transfers the inoculated tomato plants appeared to be segregating into groups showing different symptoms. A programme of selection was begun and eventually two distinct strains of T.S.W. virus were separated (A and Etch).

Subsequently a third strain (R), which is intermediate between strains A and Etch, has been separated from new sources of material and, more recently still, what appears to be a fourth strain. Whether this fourth strain (W.R.S.) is in reality a strain of T.S.W. or a distinct virus is at present under investigation.

As a result of our studies of these strains we believe that the original material on which work was done between 1933 and 1941 was either strain A or a mixture of strain A with the closely related strain R.

(b) *Protective infection.* When tomato plants were infected first with the milder Etch strain and then, when Etch symptoms had developed, they were inoculated with strain A, they developed some primary lesions typical of A at the site of inoculation but did not develop the general systemic symptoms of A and there was a marked difference between these plants and the control plants of the same age inoculated with A only, which eventually died. The Etch strain affects the growth of the plants but it protects them against the more severe strain A.

(2) *Metabolism of Tomato Plants Infected with T.S.W. Virus.*

Plants were harvested 0, 7, 15 and 21 days after infection. The *relative growth rate* for both leaf and stem was slightly lower for infected plants than healthy ones during the first fortnight but thereafter the infected plants practically ceased to grow.

The concentration of protein-nitrogen did not change very markedly in the healthy plants (either in the leaves or stems) during the 21 days but the concentration in stems of infected plants increased by over 20 per cent. The concentration of protein-nitrogen was generally higher in the healthy than in the infected plants but the differences were not great.

The concentration of protein-phosphorus was consistently higher in both leaves and stems of infected plants than in the controls at comparable times. The actual amount of protein-phosphorus per plant increased in leaves and stems of both healthy and infected plants throughout, but there was little difference in the amounts present in healthy and infected plants.

The nitrogen-phosphorus ratio of the leaf tissue of healthy plants increased throughout, whereas that of the leaf tissue of infected plants remained consistently lower.

It is of interest to note that the protein-phosphorus of the leaf tissue formed a greater proportion of the total phosphorus in infected than in healthy plants.

The above results have suggested other lines of investigation and will therefore be discussed more fully in subsequent reports. From the data already obtained it appears that strain *A* of tomato spotted wilt virus (the one used for these experiments) contains a higher percentage of phosphorus than does tobacco mosaic.

(3) *Effect of Heat on T.S.W. Virus in the Plant.*

The effect of heat on the virus in growing plants was investigated in cabinets in which temperature and lighting could be controlled. Temperatures which inactivated the virus *in vitro* were found also to inactivate it in the plant—but at a much slower rate. When infected plants were exposed to a temperature of 40° C. for 72 hours, for example, in one trial there was complete inactivation of virus, and in another 96 per cent. of the virus had been inactivated. At 45° C. the virus was inactivated completely in 24 hours, but the plants themselves had suffered badly.

Plant Physiology

The central theme of the plant physiological work at the Institute has in the past been the study of the growth rates of plants of agricultural importance. Opportunity has now been taken to embark on another field of investigation, viz. the study of growth promoting and regulating substances in plants, and this work is still in its preliminary stages.

1. Growth Studies.

(1) *Net Assimilation Rate.*

The most important phase of the study of plant growth has been a critical review of the concept of net assimilation rate and its value in interpreting growth data. The meaning of this index was described in the Report for 1937–38 and the lines upon which it would be further investigated were there indicated. This study is now completed.

The theoretical derivation of the formulae used for calculating the expression of growth rate over specific time intervals has been examined, and errors inherent in their use under certain conditions have been indicated. A method based upon graphical interpolation has been developed for estimating mean assimilation rates in cases where it is known that the use of the approximate formulae would lead to considerable error.

The most suitable basis upon which to express net assimilation rate has been examined in detail. Leaf weight, leaf area, leaf total-nirogen, and leaf protein-nitrogen have all been used for this purpose. Leaf protein-nitrogen has proved a more adequate index of the "internal factor" for growth. Leaf-weight and leaf area are suitable indices of active "growing material" only during early vegetative growth. Leaf protein-nitrogen is suitable for a considerably longer period, provided that nitrogen is in short supply.

All of the above findings were established both by reference to data of previous experiments and to a fresh growth experiment with *Phalaris tuberosa* L., in which the nutrient treatments comprised two levels each of nitrogen and phosphorus in all combinations.

(2) *Studies of the Safflower Plant.*

The shortage of drying oils has directed attention to the cultivation of suitable oil-bearing crops in Australia. Safflower (*Carthamus tinctorius* L.) is an oil crop which has recently been introduced into Australia, and in 1947 a comprehensive experiment was carried out under glasshouse conditions to obtain information on the basic growth characterisics of the plant to serve as a background for further agronomic studies. Counts of the various plant parts such as leaves, number of branches, inflorescences and seeds per inflorescence were made throughout the life cycle, in addition to the customary dry weight determinations of such fractions. A large body of data was collected—only some of the features established can be mentioned here.

At maturity the plants were about 120 cm. tall and had about nine branches in addition to the main stem, most of which carried inflorescences. Approximately one-third of the total number of leaves was carried on the main stem.

In general it was established that safflower has a lower stem weight ratio, and higher leaf and inflorescence weight ratios than most cereals and linseed.

Other aspects studied were the water relationships and flowering characteristics. It was shown that the quantity of water transpired per unit of dry weight elaborated was not appreciably higher than that found for cereals such as wheat, The variations from the normal rate of flowering were highly correlated with mean daily temperature.

(3) *Nucleic Acid Phosphorus.*

Phosphorus is well known to be an important element in plant nutrition and is a constituent of nucleic acid, a compound intimately connected with the plant's protein metabolism. As a preliminary to a study of the distribution of phosphorus within the plant and of some other aspects of phosphorus metabolism, an investigation of methods, suitable for plant materials, for the estimation of nucleic acid phosphorus, has been made, and satisfactory procedures established.

2. Plant Growth Substances.

Although at least three groups of plant hormones are now recognized, the immediate concern has been with that group which controls and regulates growth. Despite the fact that this is a relatively new field of investigation, several practical applications are already well known. Among these may be mentioned the use of synthetic hormones (a) to promote rooting of cuttings, (b) to control the dormancy of fruit and foliar buds, (c) to prevent pre-harvest drop of fruit and (d) as selective herbicides, the most familiar examples being 2–4 dichlorophenoxyacetic acid (2, 4–D) and 4-chloro-2-methyl phenoxyacetic acid (Methoxone). Considerably less, however, is known as to the essential mode of action of these compounds, and the corresponding parts played by the naturally occurring hormones, and it is with such aspects that the work of this Department will be concerned.

An essential preliminary to such work is facility with methods for estimating the hormone content of plant materials. The quantities involved are so minute that bio-assay methods, which demand special and closely controlled conditions, must be used. During the period covered by this Report, a prototype chamber for the culture of test plants has been built and the experience so gained used in the design of a more permanent chamber with enhanced facilities. Experience with the various methods available has also been acquired and suitable modifications for the projected work established.

The test plants are the coleoptiles or first shoots of oats which must be grown and manipulated at a temperature of 25° C., a relative humidity of 85–90%, and under non-phototropic illumination, i.e. light that will not induce curving or bending of plants.

Briefly, such plants when three days old are decapitated and small agar jelly blocks containing hormones or plant extracts are applied unilaterally to the stumps. Any hormone incorporated in the agar will diffuse down to the side of the plants immediately below the blocks and accelerate growth on that side, thus causing bending away from the blocks. By means of suitable calibration, the magnitude of the curvature is used to estimate the quantity of hormone present.

Entomology

The work of the Department of Entomology during 1943–47 continued to be related to problems associated with war and reconstruction. Investigations of the insect pests of stored grain were continued. There was a continuing increase in the number of enquiries under the advisory services to the State Departments of Agriculture and Woods and Forests; in addition, miscellaneous enquiries concerning insects of importance in such fields as medicine, hygiene and the building industry came forward in increasing numbers. The Department welcomes these enquiries as a valuable means of keeping the research workers informed of the practical entomological problems present in the State.

1. THE INSECT PESTS OF STORED WHEAT.

In a previous report (1941–42) were described the measurements of temperature, humidity and carbon-dioxide concentration which were made in the microenvironment of insects living in stored wheat, and some of the earlier results of laboratory experiments with the grain weevils *Calandra oryzae* L. and *Rhizopertha dominica* Fab. were also reported. During 1943–45 these studies were continued. Particular attention was paid to the influence of temperature and moisture on the rate of increase of weevil populations infesting wheat in store. The phenomenon of the "heating" of wheat stored in bulk was also studied.

The total number of eggs laid and the rate of oviposition by the small strain of *Calandra oryzae* were found to be influenced by the temperature and moisture content of the wheat and by the density of the insect population. The greatest number (384) of eggs per female was laid at 25·5° C. in wheat of 14 per cent. moisture content when there was a population of one insect to 50 grains of wheat. The rate of oviposition was also greatest in this enviroment. Nearly as many eggs were laid in wheat at 20 per cent. moisture content and at other temperatures between the limits 23° C. and 29° C., but the number of eggs decreased greatly outside this range of temperature and in wheat of 12 per cent. moisture content or drier. There were also fewer eggs laid when the population was increased to ten weevils in 50 grains of wheat.

The egg developed most rapidly at 32° C. and the larva at 29° C.; the time required for full pre-imaginal development was shortest at about 30° C. and increased both above and below this temperature. At 29° C. in wheat of 14 per cent. moisture content *Calandra oryzae* (small strain) developed from egg to adult in 25 days. In drier wheat the weevils grew more slowly; for example, in wheat with a moisture content of 11 per cent. they required 27·4 days at 29° C. to reach the adult stage.

The mortality rate of *Calandra oryzae* (small strain) was greatest in dry wheat outside the temperature range of 18° C. to 32° C. It approached 100 per cent. at all temperatures as the moisture content of the grain approached 10 per cent.; the survival rate approached 100 per cent. between the temperature limits 19° C. to 29° C. as the moisture content of the grain approached 14 per cent. The eggs were less susceptible to heat and dryness than any other stage of the life cycle. The first larval instar was the most susceptible stage in the life cycle. If the conditions were sufficiently favourable for a high survival rate of first instar larvae the survival rate of the later stages was nearly 100 per cent.

Having measured the influence of temperature and moisture content of grain on the survival rate, rate of development, and fecundity of the weevils, it became possible to estimate the rate of increase of populations of *Calandra oryzae* living in grain at different temperatures and moisture contents. It was shown that no increase was possible in grain of 10 per cent. moisture content or drier. In grain of 11 per cent. moisture content the population increased about 100-fold in 100 days at 30° C. and more slowly at other temperatures between 19° C. and 31° C.: outside these temperature limits no increase was possible in grain of 11 per cent. moisture content. In grain of 14 per cent. moisture content the limits of temperature betwen which population increased were wider (18° C.–34° C.) and the maximum rate of increase was greater—about 600-fold in 100 days at 30° C.

These results indicated that the greatest damage from weevils would result when moist wheat was stored in a warm situation; and would be least when wheat was harvested as "dry" as possible and stored in a climatic zone where either the temperature or the moisture content of the grain was likely to remain outside the limits favourable to *Calandra oryzae*. The wheat stored in South Australia during the second World War remained relatively free from damage by insects largely because these precepts were followed and every attention was paid to the prevention of primary infestation.

In other States much wheat was stored in bulk. Two problems were important: the "heating" of deep pockets in the wheat and the infestation of the surface layers by weevils and other grain insects. The programme of laboratory experiments described above was therefore extended to study the rate of respiration of the different stages of *Calandra oryzae* in wheat at various moisture contents and at various temperatures. The behaviour of adult weevils in small laboratory "bulks" of wheat was also studied.

Eggs of *Calandra oryzae* which had been laid into wheat at 14 per cent. moisture content were allowed to develop at 29° C. At intervals the rate of oxygen consumption of the developing weevil was measured at 30° C. The oxygen consumption increased from about 2 cubic mm. of oxygen per insect per hour at 8 days to about 25 cubic mm. on the 16th day when most of the insects were in the prepupal stage, and then fell to about 5 cubic mm. on the 22nd day when the adults were about to emerge.

The oxygen consumption of larvae twelve days old at 29° C. and of adults seven days old at 29° C. was measured at a number of temperatures between 12° C. and 34° C. With larvae the oxygen consumption rose from about 2 cubic mm. per insect per hour at 12° C. to about 15 cubic mm. at 31° C. With adults the corresponding figures were 1 cubic mm. at 12° C. to a maximum of 6 cubic mm. at 32° C.

Having established these data and knowing the rate of increase of populations in any particular environment, it was possible to estimate the rate of temperature increase in bulk wheat containing *Calandra oryzae* at particular levels of population density. It was shown that, starting with a population of 1 insect in 2,000 grains of wheat in the centre of a 16 foot bulkhead, the wheat would increase in temperature by about 16° F. during 12 months. By similar calculations it was shown that the observed "heating" of wheat stored in bulk could be accounted for solely in terms of the heat generated by the respiration of insects present in such low numbers as to be negligible from the point of view

of damage to the grain. The activity of the insects in these deeper layers of grain raises the temperature of the grain, killing the immature stages and driving the adults to the surface. Thus the occurrence of "hot pockets" at the deeper levels and the restriction of heavy infestation to the surface layers are related phenomena and both can be explained in terms of the heat generated by the activity of the insects and the relatively low rate of heat transfer through wheat.

Experiments with small experimental "bulks" of wheat in the laboratory confirmed these conclusions. Various numbers of *Calandra oryzae* were introduced into various situations in cylinders containing wheat. It was found that the weevils moved through the grain to situations near the surface where the temperature was low enough for them to persist.

These data suggest that complete protection from insect damage might be provided for wheat stored in bulk simply by placing a layer of heat-insulating material over the surface of the wheat. This hypothesis was not put to the test largely because, with the end of the War, wheat was no longer required to be held in quantity for protracted periods.

The above statement refers exclusively to work done with the small strain of *Calandra oryzae*. The other serious primary pest of stored wheat in Australia is *Rhizopertha dominica*. A parallel investigation was carried out with this species. The ecology of *Rhizopertha dominica* differs in detail from that of *Calandra oryzae*: the former can thrive in drier wheat and at higher temperatures than the latter, but *Calandra oryzae* is better able to establish itself in sound grain than *Rhizopertha dominica;* but the principles as they relate to pest control in sound grain are similar for the two species. The work is reported fully in the published papers listed elsewhere in this Report.

During the investigation of the ecology of *Calandra oryzae* it was discovered that a second strain of this species exists in Australia. It is morphologically identical with the common strain except that it is larger. There are, however, striking differences in the physiology and ecology of the two strains. The small strain prefers wheat to maize, develops more rapidly and is less variable in the time required to complete development. It flies less readily than the large strain. The large strain prefers maize to wheat and flies quite readily on a warm day. Both strains are larger when reared on maize than when reared on wheat but under comparable conditions the relative difference in size is maintained. The two strains are inter-sterile.

The investigation of these insects of stored product was concluded in 1946.

2. INSECTS OF PASTURES.

With the development and continued improvement of pastures in the higher rainfall areas of South Australia, certain native insects which were not formerly of much importance have become increasingly destructive of the more valuable forage plants now being grown. The areas concerned are mostly in the south-east of the State, but some also occur on Kangaroo Island and in the southern parts of Eyre Peninsula. Three groups of insects form an ecological complex which is best considered as one general problem. The "pasture cockchafer", *Aphodius howitti* Hope, has a life cycle which is well adapted to the life cycle of certain annual forage crops—subterranean clover and other annual clovers and Wimmera

rye-grass and other annual grasses—which now are the commonest pasture species in these areas. When pastures containing these annuals are dressed with superphosphate, fertility may be built up to a level where *A. howitti* may thrive. The area may become particularly favourable to *A. howitti* if a good balance between grass and legume is not maintained (i.e. if the clover becomes predominant) and if the pasture is heavily grazed. Both these conditions seem to favour the insects because they produce a high level of nitrogen in the soil and result in a relatively thin cover of stubble in the autumn. The favourableness of the latter condition seems to be associated with the egg-laying preferences of the beetle.

When pastures composed of annual species are managed in such a way as to reduce their favourableness to *A. howitti* by maintaining a good balance between clover and grass and by preserving a relatively good cover of stubble during the autumn, they may become favourable for the multiplication of "white grubs". These are the larvae of several species of Scarabeidae which live at the base of the plants and feed on the roots. When they are numerous the carrying capacity of ths pasture may be greatly reduced.

When the annual grasses are replaced by certain hardy perennial grasses, the pasture seems to become less favourable for *A. howitti* and for white grubs; but this modification may make the pasture highly favourable for two native species of caterpillar. The underground grass-grub, *Oncopera fasciculata* Walk., prefers light soil and *Philobota productella* Meyr. prefers heavier soil, but both have similar habits. The larva forms a silk-lined burrow in the soil whence it emerges at night to browse on the green parts of the growing plant. Both species may reach plague numbers when the weather favours them and may do serious damage over extensive areas.

A survey of the problem presented by this complex of pasture pests was made during 1944–46 and it is intended that the results of this survey, as summarized above, will form the basis for more detailed work. It is hoped that a thorough investigation of the ecology of these species may reveal modifications of farm husbandry which may reduce the risk of their increasing to plague numbers.

3. INSECT PESTS OF HORTICLUTURAL CROPS.

The fruitgrowers of South Australia have been fortunate in that they do not have to contend with either of the two species of fruit fly which are present elsewhere in Australia: although it is generally agreed that they could thrive in the environment provided by orchards in South Australia.

On January 30th, 1947, the Queensland fruit fly, *Strumeta tryoni* Frogg., was discovered in nectarines in a garden in Glen Osmond, a suburb of Adelaide. A survey revealed that the fruit fly occurred in a number of gardens in the southern suburbs, and a separate infestation was also found at Glenelg, another suburb about five miles away. In both cases the infestations proved to be limited and a vigorous campaign of eradication was undertaken by the State Department of Agriculture with advisory assistance from the Department of Entomology.

The eradication campaign was based on the following procedures: in each case an area with its boundaries about a mile beyond the infestation was set aside for treatment. All fruit was stripped from possible host-plants and destroyed and every effort was made to maintain the area in a completely host-free condition

until well into the following summer. At the same time poison bait sprays were applied at frequent intervals and D.D.T. sprays were also applied in particular situations. The active measures associated with the campaign were conducted by the Horticultural Branch of the Department of Agriculture of South Australia.

4. BIOLOGICAL CONTROL OF INSECTS.

The Department of Entomology in co-operation with the C.S.I.R. Division of Economic Entomology and of the Horticultural State Department of Agriculture, has introduced into South Australia number of beneficial insect parasites.*

In the last Report the introduction was mentioned of *Microphanurus basalis* Woll., an egg-parasite of the green vegetable bug, *Nezara viridula* L. This parasite has become well established and has effectively reduced the numbers of its host.

The black scale *Saissetia oleae* Bernard is a pest of citrus in South Australia. During 1943 to 1947 *Metaphycus helvolus* Comp. was reared in the insectary and from time to time colonies were liberated around Adelaide and in the citrus areas of the Murray Valley. The parasite has been recovered from most of the areas where it was liberated but the pronounced fluctuations in the populations of the host, which may be attributed largely to fluctuations in the weather, make it difficult to estimate the chances of *M. helvolus* becoming permanently established in any particular area and the influence it may have on populations of its host.

In the insectary *Metaphycus helvolus* was reared on *Saissetia oleae* Bern., *Coccus hesperidum* L., *Saissetia nigra* Nietn., and *Eucalymnatus tessellatus* Sign., and it is considered that it may breed on any *Lecanium* type scale which it can penetrate with its ovipositor. The soft brown scale *Coccus hesperidum* is often associated with *S. oleae* on citrus in South Australia and therefore may be an important alternative host for *M. helvolus.*

A survey was made of the parasites already established in South Australia on *S. oleae* and *C. hesperidum.* The list may not be exhaustive and the interrelationships of some of the species have not been worked out fully:

Rhizobius ventralis Ehr. Occasionally very abundant.
Metaphycus lounsburyi How. Primary; widespread, but not often abundant.
Quaylea whittieri Gir. Secondary; scarce.
Myiocnema comperi Ashm. ? Secondary on *M. lounsburyi* in black scale and on *Coccophagus scutellaris* on brown scale; sometimes abundant.
Myiocnema sp. ? Secondary; scarce.
Cheiloneurus sp. ? Secondary; scarce.
Microterys flavus How. Primary; scarce.
Coccophagus scutellaris Delm. Primary; abundant in *C. hesperidum,* rare in *S. oleae.*
Alphobetoideus comperi Ashm. Scarce.
Adelencyrtus simmondsi Comp. Abundant in one situation.
Metaphycus alberti How. Primary; widespread and abundant.

* Mr. H. W. Simmonds worked as a part-time officer of the Department of Entomology from January, 1943, to March, 1948, and was in charge of this work in South Australia. This section of the report has been condensed from reports prepared by Mr. Simmonds but not yet published.

All these species were recovered from *Coccus hesperidum* and all except *Metaphycus alberti, Adelencyrtus simmondsi* and *Alphobetoideus comperi* were also reared from *Saissetia oleae*. Of the others *Coccophagus scutellaris* was abundant in *C. hesperidum* and rare in *S. oleae,* whereas *Myiocnema comperi* was abundant on *S. oleae* but les common on *C. hesperidum.* The survey failed to reveal the presence of *Scutellista cyanea* and it is concluded that this species, which is valuable in other parts of Australia, is absent from South Australia.

The red scale *Aonidiella aurantii* Mask. occurs on citrus grown on the Adelaide plains but is virtually absent from the more important citrus areas in the Murray Valley. The most imporant predator of red scale in South Australia is the coccinellid *Lindorus lophanthae* Blais. Unidentified chrysopid lacewings were also observed feeding on red scale and these were occasionally quite numerous. A parasite which has been identified as *Aphytis chrysomphali* Mercet was present though usually in small numbers. Its distribution seemed to be quite patchy.

A colony of the Chinese race of *Comperiella bifasciata* How. was received from C.S.I.R. Division of Economic Entomology in January, 1943. This was reared in the insectary and from time to time colonies were liberated, mostly on the Adelaide plains but also in the Torrens Valley and at Mypolonga; altogether about 10,000 females and rather more males were liberated during the four years 1943–47. Recoveries have been made from most of the areas where the parasites were liberated, but it is difficult to estimate the ultimate value of this parasite, partly because of the wide fluctuations in the numbers of red scale and partly because of the widespread use of fumigants and sprays against red scale.

Both *Pteromalus purparum* L. and *Apanteles glomeratus* L., which are parasites of the cabbage white butterfly have been recovered from most of the places where they were liberated. The potato moth parasite *Chelonus* sp. was liberated in a number of situations during 1944, 1945 and 1946, but no recoveries have been made as yet. Colonies of two species of Chrysomelidae, *Chrysomela hyperici* Forst. and *C. gemellata* Rossi were obtained from C.S.I.R. in November, 1944, and liberated on stands of the weed *Hypericum perforatum* L. (S. John's Wort) at Penwortham and Yankalilla. Additional colonies were obtained in 1946 and 1947 for liberation at other localities, including Port Lincoln and Belair. This work was undertaken in association with the Department of Agriculture. Active establishment and spread of the beetles has been observed at the first three localities mentioned.

5. STUDIES IN INSECT ECOLOGY.

In earlier reports the results were presented of a study of the biology of *Thrips imaginis* Bagnall. Experimental work on the biology of this species was concluded about 1936. But the daily records of the numbers of *Thrips imaginis* in roses in the garden at the Waite Institute which was begun in 1932 were continued until 1946 (except for 1944). The fourteen years' records have been used to measure the strength of the association between the numbers of thrips and certain components of the physical environment as determined by weather. It was found that about 80 per cent. of the variance of the population from year to year could be ascribed to four components of the physical environment. The most influential component was one related to rainfall and temperature during

the preceding autumn. This was considered to operate chiefly through its influence on the germination and growth of the annual plants which are important hosts for *Thrips imaginis*.

In the absence of any predators, parasites or disease or other components of the environment which are usually considered "density-dependent", the data were examined to discover any mechanism which might keep the population "in balance" with its environment. It was considered that "density dependent" components were neglible during the time that the population was increasing and that during the time when the population was decreasing the physical environment might assume the qualities of "density-dependence".

6. MISCELLANEOUS.

In August, 1943, the Department of Woods and Forests discovered a bark beetle working on the remnants of recently felled *Pinus laricio* at Wirrabara. The beetle was subsequently identified through the courtesy of the United States Department of Agriculure as *Ips grandicollis* Eich. In the United States this species is known as the southern pine engraver. It is not of major importance.

In February, 1946, a few specimens of yellow scale *Aonidiella citrina* Coq. were found on citrus and on vines adjacent to citrus at Waikerie. This species is a serious pest of citrus in other countries. It has been known to be present elsewhere in Australia but this was the first authentic record from South Australia.

During the spring of 1946 a serious plague of carrot aphis *Cavariella aegopodii* Scop. occurred in the hills behind Adelaide and on the plains near the foothills. This aphid overwinters on willow and the winged migrants move to carrots in the spring. During 1946 the damage done to young carrots was most extensive.

In November, 1946, the common agricultural weed *Carthamus lanatus* L. (saffron thistle) was reported to be heavily infested by an aphid; this was identified as *Anuraphis helichrysi* Kalt., which is known from all continents as a feeder on various composites. The only previous record of its occurrence in Australia appears to be from *Chrysanthemum* in New South Wales. The alternate hosts of this aphid in other countries are various species of *Prunus,* on which it may be a pest; it is known as the "plum aphis" in England. A search was therefore made to determine whether it might occur on plums in South Australia. With the assistance of the Horticultural Branch of the Department of Agriculture, it was found in an orchard at Cudlee Creek near Adelaide, where it had caused economic damage extending over a number of years to plum trees of the varieties Wickson and Climax.

Plant Pathology

The Advisory service to the Departments of Agriculture and of Woods and Forests for which this department is responsible provides a valued link with the problems of plant disease in this State. It keeps the research worker in contact with field officers of the State Departments concerned and enables him to keep abreast with the field side of any problem which is his immediate concern. It also enables the department to acquire an overall picture of the situation regarding plant diseases in the State.

In a brief review it is impossible to do justice to the range of matters that have been the subject of enquiry over a five-year period. Reference will be limited to disease occurrences of major significance which, as might be expected, have been associated closely with the vagaries of the weather from year to year.

In 1947 rust (*Puccinia graminis*) and to a lesser degree "takeall" (*Ophiobolus graminis*) were widespread and it was estimated that a loss of at least 4,000,000 bushels was sustained on account of these diseases. The problem of averting losses from rust lies in the use of resistant varieties and progress in this direction is referred to elsewhere in this report. An account of work on "takeall" appears below.

During the period under review, several summers were marked by an unusual rainfall which led to the development of diseases seldom important in South Australia. The diseases thus developing included Leaf Spot of tomatoes (*Septoria lycopersici*), potato blight (*Phytophthora infestans*), the summer spot phase of scab (*Venturia inaequalis*), several diseases of significance for minor crops and the potentially destructive downy mildew of vines (*Plasmopara viticola*). In 1946 downy mildew, which had not been recorded from within the State in the previous 20 years, defoliated vines in an isolated settlement at Coonawarra and impaired the vintage. In the following year it occurred in a district about 200 miles distant from Coonawarra but neither in this district, where prompt spray measures were taken, nor in the main vine growing districts of the Barossa and Murray Valleys, where it appeared sporadically in the following year, did it cause appreciable damage.

(1) *"Takeall" Disease of Wheat.*

Efforts to expand knowledge concerning root-rot diseases of wheat, especially of "takeall" of "haydie", have been maintained. "Takeall" is caused by the fungus *Ophiobolus graminis* which attacks the roots to produce the symptoms of seedling blight or whiteheads ("haydie") with which many wheat-growers are familiar. It facilitates understanding of this disease if we consider that its problems fall into two groups. First to consider are those concerned with the fate of *Ophiobolus* during the period between successive wheat crops; and second, those concerned with the progress of the disease once infection has started. We have been interested in both classes of problems. The question of survival of *Ophiobolus* between successive wheat crops is intimately bound up with the well known fact that many grasses occupying land between successive wheat crops are susceptible to infection by *Ophiobolus*. Locally, barley grass (*H. leporinum*), silver grass (*Vulpia*) and the brome grasses are most important. These volunteer inhabitants of wheat lands during their ley period are important in two ways. In ordinary soil, in the absence of living roots, *Ophiobolus* is virtually incapable of growth and would, for reasons touched on later, be eliminated fairly quickly. The presence of susceptible annual grasses may, however, overcome this disability. Each year their roots provide an opportunity for renewed active growth and infected in this way they also provide an important source of infection for succeeding wheat crops.

Little is known concerning fluctuations in the natural infection of grasses from year to year but observations in the field suggest that it varies considerably. Investigations on the survival of dormant mycelium, the form in which

the fungus *Ophiobolus* is present at the time wheat is starting to grow, are easier to effect. They reveal that survival is dependent on (a) the character and especially the water content of the soil in which they repose, and (b) the character of the root or other material with which the dormant mycelium is associated. Details cannot be elaborated here. It is sufficient to say that the whole problem of survival appears to turn on the question of general microbiological activity in the soil. Evidence for the importance of this activity in the life cycle of such diseases as "takeall" is by no means new but all our results suggest that microbiological activity is important for its effects on the survival of potential infective material rather than for its effects once the disease has been established, an aspect which has been emphasized elsewhere.

On the second side of the general problem, the consideration of conditions influencing the progress of the disease once infection has been established, much more work has been done. This work has been done almost wholly with plants grown in large pots in the glass-house where it is possible to assemble a variety of soils and treat them in numerous ways with different fertilizers, watering régimes, etc., that would not be practicable under ordinary field conditions. Some of the information accumulated in this way is difficult to interpret because it is hard to find satisfactory quantitative terms in which the effects of the disease on fully developed plants can be expressed. Heights of plants, total dry matter content, total and individual grain weights, the proportion of whiteheads or grain/straw ratios and water losses provide means by which disease effects can be measured; but their interpretation is complicated by the fact that variations in most of the above quantities may not be peculiarly the effect of disease. Non-diseased plants often respond to treatments in somewhat similar terms. "Infection ratings" while useful as measures of disease with seedlings have been found unsatisfactory for mature plants. Apart from any objection to its arbitrary and somewhat subjective character, we have found that "ratings" may be influenced by treatment in a way that is often poorly reflected in other symptoms. Experimental plants may, for example, have much blackened roots and stem bases entitling them to a high "infection rating" and yet in respect to height and grain production, symptoms that the farmer would expect with "haydie", there might be no difference from plants given a much lower rating.

The difficulties here briefly described have led to the view that the problem of interpreting the effects of various treatments on the progress of "takeall" must await a deeper understanding of the pathology of infection by *Ophiobolus* and work with this objective is being pursued.

No common wheat variety is known to possess marked qualities of resistance to *Ophiobolus*, so that prospects for controlling "takeall" by developing resistant varieties are not promising. Oats, however, are well known for their resistance to "takeall" and an investigation of its basis has been made. The leaves of oats, though not their roots, have been found to contain a water soluble substance which strongly represses the growth of *O. graminis* in solution culture. Extracts of similar concentrations are much less repressive in their effects on the growth of *O. graminis avenae* which occurs on oats in England. Detailed studies of these inhibiting extracts have been made to discover (a) the mechanism of their inhibitory action, (b) the chemical properties of the extract, and (c) methods by which the extract may be purified. Extracts have been so purified that their potency per unit volume has been increased 46-fold.

(2) *Pre-emergence Rotting of Peas.*

The need to stimulate local production of vegetable seed peas during World War II attracted attention to the disease affecting this crop. Of these diseases perhaps the most serious was a pre-emergence rotting of wrinkle-seeded peas which in many cases depleted "stands" considerably. Field trials at an early stage of the investigation revealed that such losses could be materially reduced if seed was dusted prior to planting with "Spergon" or its Australian equivalent "Tetroe". Copper containing dusts (e.g. "copper carbonate"), so useful for dressing other kinds of seeds, was found to be objectionable because seed so treated passed very poorly through the ordinary seed drill. With some samples a high proportion of the passed seed was split or mangled worse. Various species of *Pythium*, but especially *P. debaryanum*, were isolated from affected peas and their importance as the primary cause of pre-emergence rotting established by inoculation experiments.

Although the pathogenic nature of pre-emergence blight was clearly established it was also found that its development was very markedly conditioned by the water content of the soil. By using infested soil in a series of pots whose water contents varied from near-wilting to near-saturation, emergences were obtained which ranged from approximately the maximum possible, with soil near the wilting point to nil, with soils at high water content. Mechanisms that would possibly account for these different behaviours have also been investigated. At least part of the difference appears to be due to the relative effects which different water contents have on the diffusion from peas of substances stimulating the activity of *Pythium* in the soil. The nature of these substances has not yet been ascertained but it is of interest to note that wrinkle-seeded (vegetable) varieties yield them much more readily than do smooth-seeded (field) varieties. These observations may account for the fact that smooth-seeded varieties suffer but slightly from pre-emergence rotting in soils where with wrinkle-seeded varieties damage is extensive.

(3) *"Dieback" or "Gummosis" of Apricots.*

In 1947 the Council for Scientific and Industrial Research appointed a research officer to work on this disease with headquarters at the Institute. This disease which is of considerable economic importance in South Australia was referred to in the report for 1937–38, when it was established that it was caused by the fungus *Cytosporina* gaining entrance to the wood through wounds.

As a preliminary to further work a fairly detailed field survey of the occurrence of the disease was made in orchards in this State and in Tasmania, where it is also a serious disease. In this survey data was collected from representative orchards in both States in an effort to relate such matters as variety, stock, age of trees, soils, irrigation, fertilizer treatments and pruning practices to the health of trees. A uniform system of rating to assess tree health was adopted. It took into account both the proportion of affected trees and the severity of their infection and was designed to throw light on the relative importance of the various factors enumerated above. The most obvious general finding was an increase in incidence of disease with age, though this varies greatly from orchard to orchard. Among ten-year-old trees, 30–40 per cent. generally had at least one branch affected. Among older groups, in trees 25 years or older, several instances of 100 per cent. affected trees were found. The survey, which

also included data obtained from brief excursions into apricot growing areas of Victoria and New South Wales where the disease is generally unimportant, also provided evidence on the importance of soils irrigation, fertilizer and other cultural practices in relation to the disease, and the information gained will provide a basis for future experimental work. Considerable work has also been done on the biology and life history of the fungus associated with the disease. The regular association of *Cytosporina* with the form of "dieback" which occurs locally and its pathogenicity for apricots has been abundantly confirmed. Its life history, however, is still obscure. From evidence of the occurrence in isolated orchards of the disease which it causes it appears that the fungus can be disseminated for considerable distances by air, a mode of dispersal for which the sticky spore masses of *Cytosporina* seem ill adapted. It is suspected that *Cytosporina* may be the imperfect stage of an Ascomycete with spores better adapted to wind dispersal. With this view in mind special attention is being given to a species of *Cryptovalsa* commonly found on dead apricot twigs.

(4) *Bacterial blight of Cherries.*

This blight was prevalent in local cherry orchards during the spring of 1946. Flowers, leavs, spurs, branches and when formed, occasionally the fruits were affected. The overall loss of crop was considerable.

The bacterial nature of the disease was confirmed by repeated isolations of a bacterium which when tested for pathogenicity gave positive results. The morphological and cultural characteristics of the organisms isolated were studied and they could be referred to the genus *Pseudomonas*. It is therefore similar to, if not identical with, species that have been described from cherries and other stone fruits in America, England and elsewhere. Referring to these we have found great difficulty, however, in relating local isolates to any one of the several species that have been described. Progress on the problem seems to await better criteria for distinguishing species than are available at present and work along this line has been planned.

In the field, observations reveal that the incidence of blight varies greatly from year to year and that the weather markedly affects the susceptibility of trees. Sufficient data to say how this effect is produced has not yet been accumulated but it is noteworthy that in the spring of 1946, when the disease was severe, the flowering period of cherries was unduly prolonged. Evidence was also collected on varietal susceptibility and the influence of fertilizers, especially of nitrogenous materials. Differences in varietal susceptibility occur but they are not especially marked among the rather limited range of varieties grown locally. Heavy applications of nitrogenous fertilizers aggravate the disease.

(5) *Rind Blemish of Stored Oranges.*

Work on this project which was referred to in the previous report virtually ceased in 1942. The results of the work in so far as they relate to latent infection have been accepted for publication in "Australian Journal of Scientific Research," Series B.

(6) *Miscellaneous.*

Field trials to evaluate seed dressings for cereals and flax have been conducted from time to time with materials supplied by Imperial Chemical Industries of Australia and New Zealand Ltd. and others.

With cereals most of the trials have dealt with various organic mercurial compounds with the purpose of testing their merits in comparison with standard "copper carbonate" treatments.

The value of dressing of flax seed with organic mercurials and with non-metallic materials such as "Nomersan" has also been examined under a variety of conditions but no consistent beneficial value justifying general application has been found.

Latterly in association with officers of the Horticultural Division, Department of Agriculture, spraying trials, with the object of securing better control of *Septoria* blight in celery, have been undertaken. Growers at present normally apply Bordeaux mixture at frequent intervals for the purposes of controlling this disease. We have found that sprays containing "Fermate" or "Nomersan" as their active principle have given equally as good, perhaps slightly more, effective control than Bordeaux mixture. The trials have also revealed that frequent applications of Bordeaux mixture tend to cause stunting of the plants sprayed. The effect may be due to excessive copper received by the plants.

Climatology

The agricultural industry is based on the interaction of plants, animals, soils and weather. Since it foundation, the Waite Institute has take a special interest in climatology as applied to the agricultural and biological problems of Australia. In the study of the geographical distribution of plants, animals and soils a knowledge of climatic conditions is also of fundamental importance.

The factors which are of greatest significance are the amount, distribution and reliability of the rainfall, and the temperature and humidity. The efficiency of the rainfall is determined to a marked extent by the evaporative power of the air. In the earlier work at the Institute, the index of this efficiency has been estimated in terms of Transeau ratio of precipitation to evaporation or the Meyer ratio of precipitation to saturation deficit. It has been increasingly obvious to those making frequent use of these indices that a constant ratio rarely holds over a wide range of climate extending from the temperate conditions to the tropics. The ratios appropriate to tropical conditions are generally lower than the corresponding ratios for temperate conditions, and this similarly applies to comparisons between summer and winter. For example, in South Australia a Transeau ration of 1 : 3 has been used for those months with an evaporation of less than 6 inches, and 1 : 4 for those with more than 6 inches. An examination of a variety of data has made it possible to suggest a new index, namely the ratio of precipitation to some power of evaporation:

$$\frac{P}{E^m} = \text{moisture index}$$

when P is precipitation,

E is evaporation from a free water surface,

m is a constant with a probable value of 0·75.

The estimation of evaporation in any locality is not a simple matter. Much has been done in Australia by standardizing the evaporimeter tank, but the

values obtained with this instrument are still markedly influenced by the exposure of the tank. Interpolation to localities where evaporimeters are not installed is usually made on the basis of saturation deficit determined from mean temperature and relative humidity and this relationship is usually satisfactory when each month is treated separately. Evaporation also depends on solar radiation and, as this latter determines temperature and, as temperature is the more important parameter determining saturation deficit, a relationship between evaporation and temperature may be expected.

These two climatic expressions are, however, out of step with each other; at the Waite Institute the curve of evaporation throughout the year is some thirteen days earlier than the temperature curve. It has been found, however, that if the temperature curve is displaced to bring it into phase with the evaporation curve the relationship between evaporation and phase displaced temperature can be expressed by a simple equation. The phase is calculated in each case by simple Fourier analysis.

This method of wave-form analysis can also be used to characterize the annual march of temperature in any locality by reducing the 12 monthly values to the three characteristics of mean, amplitude, and phase expressed as lag in days behind solar radiation. This method has been used to determine in Australia the temperature homoclimes of the zones of natural occurrence of the Mexican rubber plant, guayule, *Parthenium argentatum*, and of certain species of pines characteristic of the Mediterranean environment.

The Monterey pine of California, *Pinus radiata*, is a very important economic species in Australia and its cultivation is the principal basis of afforestation in South Australia . In south-eastern Australia it has been found that temperature conditions similar to those prevailing in the Californian habitat of this pine are to be found in Kangaroo Island, the islands of Bass Strait, the coastal regions of South Australia east of the Murray mouth, the coastal regions of Victoria, and the north-east corner of Tasmania. A rainfall of 25 to 30 inches is indicated with a seasonal incidence in winter.

Annual means are not the complete expression of any climatic factor and account must therefore be taken of variability, particularly with respect to rainfall.

The two variables with respect to rainfall in South Australia are in the length of the rainy season and in the amount of influential rainfall. The relationship of the variability of the wet season to the growth of pastures in relation to fat lamb production has been the subject of special study.

Meteorological Records

Meteorological observations in connection with the work of the Waite Institute are being made at three centres: at the Waite Institute itself, at Pallamana in the Murray Mallee (north-west of Murray Bridge) and at Yudnapinna (north-west of Port Augusta).

The records for the five years 1943–47 are given in the following tables:

Monthly rainfall in inches for the years 1943–47, Waite Institute.

Month	1943	1944	1945	1946	1947
January	·95	·31	1·30	1·87	·31
February	3·56	·88	1·67	3·29	·84
March	·09	·44	·22	2·11	2·89
April	3·50	1·97	·09	1·67	1·69
May	1·23	4·30	2·31	3·10	1·58
June	3·01	·83	2·09	2·72	2·43
July	3·07	3·58	1·47	4·36	3·67
August	2·82	·44	4·00	2·65	3·69
September	3·03	·79	3·23	1·69	2·65
October	1·32	2·22	3·53	1·59	3·96
November	·44	2·32	2·76	2·63	1·80
December	·75	1·73	1·39	2·23	2·26
Total	23·77	19·81	24·06	29·91	27·77

Monthly evaporation in inches for the years 1943–47, Waite Institute.

Month.	1943.	1944.	1945.	1946.	1947.
January	7·89	8·29	7·84	7·85	8·47
February	7·20	7·32	5·81	5·75	7·50
March	6·26	6·54	5·80	5·22	5·51
April	3·76	3·08	4·12	3·02	3·86
May	2·29	2·30	2·35	2·41	3·15
June	1·19	1·42	1·83	1·67	2·08
July	1·55	1·58	1·66	1·72	1·53
August	1·86	2·32	1·88	2·02	2·16
September	2·41	3·91	3·07	2·79	3·22
October	3·76	4·66	3·82	3·94	3·86
November	5·70	5·89	4·78	5·82	5·32
December	7·00	7·24	8·19	6·69	6·51
Total	50·87	54·55	51·15	48·90	53·17

Mean monthly maximum Air Temperatures for the years 1943–47, Waite Institute.

Month	1943. °F.	1944. °F.	1945. °F.	1946. °F.	1947. °F.
January	84·0	82·4	80·1	82·9	83·3
February	82·3	80·1	76·9	77·1	85·9
March	81·8	79·4	75·2	72·8	76·9
April	66·4	65·2	73·1	66·5	70·8
May	61·7	60·5	65·0	65·5	68·8
June	57·4	57·9	62·3	57·2	60·8
July	56·5	56·8	56·9	59·1	56·7
August	56·5	60·7	59·4	59·0	58·5
September	62·6	68·8	62·4	62·8	62·7
October	66·8	69·6	66·7	67·1	65·3
November	72·1	77·0	72·2	74·6	71·9
December	77·4	77·5	82·6	77·6	77·2
Mean	68·8	69·6	69·4	68·5	69·9

Mean monthly minimum Air Temperatures for the years 1943–47, Waite Institute.

Month.	1943. °F.	1944. °F.	1945. °F.	1946. °F.	1947. °F.
January	62·1	59·7	58·1	62·1	61·1
February	60·4	60·0	58·3	59·2	66·0
March	60·2	60·0	54·4	56·7	58·6
April	52·3	52·3	53·5	49·8	55·7
May	47·4	48·3	50·5	51·3	53·7
June	46·2	43·4	48·9	44·8	48·4
July	44·4	44·2	42·6	46·9	45·1
August	42·6	45·4	46·9	46·1	45·3
September	46·6	51·4	47·3	45·8	47·2
October	48·5	51·4	51·3	46·8	50·8
November	52·9	56·7	54·9	53·8	52·1
December	54·9	57·8	60·4	58·7	58·0
Mean	51·5	52·5	52·2	51·8	53·5

Mean Monthly Soil Temperatures at 1 inch, 6 inches, 12 inches and 24 inches for 23 years, 1925–47, Waite Institute.

	At 1" °F.		AT 6" °F.		At 12" °F.		At 24" °F.	
Month.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	109·9	63·9	85·5	71·5	78·1	73·1	73·8	71·5
February	106·6	63·8	84·4	71·0	77·6	72·7	74·4	72·2
March	100·3	61·5	80·0	68·3	74·7	70·3	72·6	70·5
April	82·7	55·0	69·2	60·5	66·9	63·5	67·1	65·0
May	70·5	50·3	60·9	54·4	60·3	57·7	61·4	59·8
June	62·9	46·5	55·2	50·1	55·1	52·8	56·5	55·1
July	61·0	45·5	53·5	48·6	53·2	50·9	54·2	52·8
August	64·5	46·5	55·8	50·0	54·3	51·8	54·5	53·0
September	73·1	49·5	61·7	53·7	58·6	55·3	57·5	55·7
October	83·9	53·8	69·4	58·8	64·3	60·2	61·9	60·0
November	95·9	59·0	77·5	64·5	70·6	65·8	67·0	64·8
December	105·2	62·5	83·0	69·1	75·3	70·2	71·2	69·0
Mean	84·7	54·8	69·7	60·0	65·8	62·0	64·3	62·4

Wind velocity at eight feet from the ground from Cup Anemometer for years 1943–47. Waite Institute. Miles per month.

Month	1943.	1944.	1945.	1946.	1947.	Ten years Mean, 1938–47.
January	3,326	3,326	3,215	3,389	2,900	3,290·2
February	3,196	3,505	2,879	3,104	3,252	2,958·4
March	2,431	3,343	2,773	2,747	2,738	2,786·0
April	3,434	2,590	2,327	1,800	1,933	2,498·0
May	2,067	2,589	2,383	2,160	2,200	2,259·8
June	2,362	1,816	2,899	1,844	2,647	2,341·2
July	3,401	2,797	2,499	3,603	2,911	2,780·9
August	2,860	2,378	3,312	2,652	2,677	2,808·6
September	2,902	2,924	3,139	2,549	2,896	2,963·0
October	2,815	3,313	2,814	2,364	3,353	2,947·3
November	3,268	3,144	2,755	2,560	2,520	2,885·3
December	3,101	4,196	2,928	3,068	3,211	3,230·1
Total	35,163	35,921	33,923	31,840	33,238	33,748·8

General Climatological Data.

The most important data, on which the studies of climatology as applied to agriculture and biology are to be based, involve rainfall, evaporation, temperature, relative humidity, and atmospheric saturation deficit.

Evaporation from a free water surface is dependent on saturation deficit, sunshine and wind. Estimates of evaporation have usually been made in the work of the Waite Institute on the assumption that it is proportional to saturation deficit when comparisons made for two or more localities relate to the same month. The ratios of precipitation (rainfall) to evaporation or saturation deficit have been found of special value in agro-climatological or bioclimatological studies. A ratio of more universal application has been found to be that of precipitation to the 0·75th power of evaporation but this ratio has not yet been extensively applied. The essential data for the Waite Institute based on the mean values for the 23 years 1925–47 are given in the following tables.

Climatological data for the Waite Institute. Mean of 23 years: 1925–47.

Month.	Precipitation. inches.	Evaporation inches.	Temperature Max. °F.	Temperature Min. °F.	Temperature Mean. °F.	Relative humidity per cent.	Saturation deficit inches of mercury.	Bright sunshine hours per day.
January	1·06	8·59	81·3	60·2	70·8	49	·387	8·7
February	1·22	7·03	81·0	60·7	70·8	52	·361	8·5
March	0·99	6·41	78·5	59·6	69·0	52	·343	7·4
April	1·99	3·99	70·2	54·3	62·2	62	·214	5·6
May	2·91	2·75	64·3	50·7	57·5	68	·152	4·2
June	2·89	1·76	58·8	46·5	52·6	75	·100	3·2
July	3·16	1·75	57·3	45·3	51·3	76	·091	3·2
August	3·12	2·28	59·1	45·8	52·4	71	·115	4·4
September	2·70	3·21	63·6	48·0	55·8	65	·157	5·6
October	1·84	4·63	68·4	50·7	59·5	60	·206	6·6
November	1·47	6·20	74·3	54·8	64·6	51	·300	7·8
December	1·17	7·83	78·8	57·9	68·3	51	·341	8·3
Total	24·52	56·43 Mean	69·6	52·9	61·3	61 Mean	·213 Mean	6·1

Month.	Ratio of Precipitation to Evaporation P/E.	Ratio of Precipitation to Saturation Deficit P/s.d.	P/E·75.	P/s.d.·75.
January	0·123	2·74	0·211	2·16
February	0·173	3·37	0·282	2·61
March	0·154	2·87	0·245	2·20
April	0·499	9·30	0·705	6·33
May	1·058	19·18	1·362	11·98
June	1·641	28·91	1·891	16·26
July	1·808	34·73	2·079	19·07
August	1·367	27·10	1·681	15·79
September	0·841	17·21	1·126	10·83
October	0·398	8·95	0·584	6·03
November	0·237	4·90	0·374	3·63
December	0·150	3·44	0·251	2·63
Annual	0·442	—	—	—

Observations at Country Centres.

(1) PALLAMANA.

Monthly rainfall and evaporation in inches for years 1943–47.

Month.	Rainfall.					Evaporation.				
	1943.	1944.	1945.	1946.	1947.	1943.	1944.	1945.	1946.	1947.
January	·67	·05	·38	2·16	0·00	11·29	12·73	9·23	9·90	9·97
February	1·20	·22	1·45	1·15	1·07	9·60	10·76	7·35	7·09	6·56
March	·10	·03	·13	2·09	3·42	9·11	9·19	7·50	5·85	6·28
April	·91	·91	·12	·71	·96	5·31	4·97	5·18	3·41	3·59
May	·83	1·79	1·18	1·60	·48	3·52	3·27	2·93	2·67	3·38
June	1·40	·33	·77	1·16	·88	2·13	2·19	2·22	1·64	2·49
July	1·09	1·48	·53	2·29	2·25	2·59	2·25	2·16	2·17	1·70
August	2·01	·17	1·64	·80	1·34	2·51	3·87	2·67	2·93	2·52
September	1·27	·44	1·62	·61	2·10	3·97	5·77	4·48	3·53	3·28
October	1·40	·74	2·19	·67	1·25	5·53	8·97	5·55	5·23	4·66
November	·82	1·03	1·57	1·64	1·44	7·96	9·84	6·79	7·28	6·07
December	1·02	·77	1·68	5·45	1·25	10·38	12·30	9·28	8·44	8·95
Total	12·73	7·96	13·26	20·33	16·44	73·90	86·11	65·34	60·14	59·45

Mean Monthly values for the period 1938–47.

Month.	Rainfall inches.	Evaporation inches.	Mean air Temperature °F.	Mean relative humidity per cent.	Mean wind velocity at 8 feet. Miles per month.
January	1·38	10·35	70·1	51	6,270
February	0·94	8·32	68·9	57	5,338
March	0·72	7·68	66·6	60	4,940
April	1·22	4·53	60·0	72	4,363
May	1·16	2·94	55·1	79	4,127
June	1·19	2·04	50·5	84	3,963
July	1·43	2·00	49·5	85	4,655
August	1·33	2·86	50·4	80	4,870
September	1·24	4·24	54·5	68	5,130
October	1·05	6·14	58·4	60	5,061
November	1·42	7·70	63·4	56	5,540
December	1·31	9·97	67·7	49	6,103
Total	14·39	68·77	59·6	67	60,360

(2) YUDNAPINNA.

Monthly rainfall and evaporation in inches for years 1943–47.

Month.	Rainfall.					Evaporation.				
	1943.	1944.	1945.	1946.	1947.	1943.	1944.	1945.	1946.	1947.
January	0·00	0·23	1·02	1·60	0·12	15·66	15·34	13·54	11·78	12·56
February	1·99	1·17	0·73	7·88	0·47	13·25	10·96	9·89	6·69	10·71
March	0·15	0·02	0·10	0·19	2·50	10·86	9·83	9·77	8·47	8·52
April	0·30	0·99	0·00	0·61	0·56	6·45	5·86	6·60	5·09	4·93
May	0·09	0·62	0·33	0·39	0·21	3·96	4·06	3·97	3·67	4·34
June	0·21	0·16	1·90	0·72	1·21	2·64	3·26	2·45	2·63	3·04
July	0·54	0·34	0·65	0·79	1·19	3·50	3·19	2·44	3·41	2·71
August	0·99	0·36	0·25	0·21	1·11	4·02	4·22	3·94	4·58	3·76
September	0·10	0·28	0·38	0·27	1·09	7·04	8·53	6·16	5·82	5·04
October	0·73	0·16	1·02	0·11	2·48	8·47	10·24	7·10	8·39	7·36
November	0·27	0·21	0·48	2·23	0·14	11·12	13·73	10·21	8·93	9·83
December	0·03	1·90	3·03	1·98	0·44	13·21	12·54	12·18	11·04	11·36
Total	5·40	6·44	9·89	16·98	11·52	100·18	101·76	88·25	80·50	84·16

Mean monthly values for the period 1939–47.

Month	Rainfall inches.	Evaporation inches.	Mean air temperature °F.	Mean relative humidity per cent.
January	·84	14·30	77·9	48
February	1·53	11·55	76·3	50
March	·68	10·31	72·4	48
April	·46	6·57	63·8	60
May	·54	4·31	58·2	65
June	·85	2·77	52·6	75
July	·74	3·01	50·9	76
August	·65	4·13	54·0	68
September	·39	6·43	59·1	55
October	·71	9·00	64·5	46
November	·69	11·12	70·3	45
December	·94	12·94	75·4	42
Total	9·02	96·44	64·6	57

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Council for Scientific and Industrial Research

Division of Soils

1. INTRODUCTION.

The Division of Soils of the Council for Scientific and Industrial Research has since its initial formation in 1929 had its headquarters at the Waite Agricultural Research Institute. The relationship has continued as a closely linked, though independent, association of the two bodies. Up to June, 1947, the Division was under the direction of Professor J. A. Prescott, of the University of Adelaide, who for nine years had been also Director of the Institute.

With the growth of its responsibilities and staff, and the increasing breadth of its research and extent of field work, the Division was organized on a sectional basis at the beginning of 1944 with the setting up of four units—Soil Survey, Soil Chemistry, Soil Physics and a small group in Soil Bacteriology, with senior officers in charge of the first three.

The operations of the Division, which have extended with the years increasingly over all States of the Commonwealth and North Australia, have been controlled from Adelaide. This organization has been made possible by the creation of permanent regional centres for soil investigations which by 1947 numbered four—Canberra, Deniliquin, Hobart, and Perth. The object of regionalization was for the more efficient study of soil problems on the spot and ultimately for the formation at each centre of a compact research unit of field and laboratory workers. These unit organizations would be linked with headquarters for direction and specialist studies, but otherwise be competent to undertake regional research in pedology, soil chemistry, and soil physics.

For many years the Division of Soils has been engaged on soil surveys and laboratory studies connected with them for State and Commonwealth agencies, and a great deal of this "service" work has continued to the time of this report. As knowledge of Australian soils was small twenty years ago, it was necessary to pioneer the way, both as to techniques for field work and in piecing together data from isolated surveys. The whole practice of soil survey under Australian conditions had to be placed on a sound basis which evolved as the coverage of larger and diverse areas was undertaken. The aim is now to map in broad categories soils of the potentially agriculturally valuable land at a scale commensurate with its assessed quality in relation to climate and irrigation. The growth of land settlement projects in the post-war years has emphasized more specifically the need for such overall mapping.

The laboratory work, which for long closely followed the surveys, also began to broaden in scope, and through war necessities the soil physics section in particular began to establish a research programme. Soil physics has been a much neglected field in Australian soil studies and the Division has in consequence had direct contact with engineering authorities, such as Highways Departments and Public Works Departments, as well as industry, in such matters as building and pavement foundations and soil cement. The Royal Australian

Air Force was also interested in soil mechanics studies, and tests were undertaken by the Division on its behalf on aerodrome sites. These connections with Government agencies are an extension of the same principle of "service" work carried out in soil surveys. Along with the routine investigations, efforts were made constantly in both chemistry and physics to combine fundamental and *ad hoc* studies in the research programme.

In practice the Division has continued to be the reference authority on soils for the Departments of Land, Agriculture, Forestry, and Irrigation in the various States in regard to land development and settlement. The Commonwealth departments created during the war years and concerned with similar matters have made free use of the Division in an advisory capacity,

2. SOIL SURVEY AND PEDOLOGY SECTION.

In the period under review considerable changes in technique, policy, and plans for survey came into operation. Since the inception of the Division in 1929, the very great bulk of work had been directed to close detailed surveys with a strong emphasis laid on irrigation areas and all had been of a "service" nature for the supply of practical knowledge of soils to State agencies requiring it for new development or solution of production problems. There had been pedological research but it was small in comparison with practical survey undertakings. Views also on types of mapping, the classification of soils and pedogenesis matured and by the end of 1947 had reached a wider and more fundamental basis, particularly evidenced by the type of surveys undertaken.

Surveys grouped themselves into four categories:

(i) intensive, such as had been used on horticultural irrigation areas in previous years.

(ii) detailed, as used for pastoral irrigation areas and soil erosion surveys;

(iii) broad scale, making use of groupings of soils as associations for mapping categories;

(iv) reconnaissance.

The intensive type has decreased to small proportions, the detailed is continuing, though in less degree than previously, while the broad scale and reconnaissance have assumed high importance.

The aim of the surveys has centred on mapping the soils of Australia on a scale suitable for the general assessment of agricultural usefulness and at the same time defining pedological relationships. The emphasis has been greater on the study of morphology and genesis of the soils. The "service" work for other organizations has been expanded to include much larger territories often using the specific unit chosen for close mapping as a base for the reconnaissance or broad scale mapping over much larger contiguous areas.

(1) Defence Investigations.

In the critical war years, 1942 to 1944, a considerable portion of field activities was directed to the survey and study of aerodrome sites and the quality of soils for such uses. An extension of this led to work on soil stabilization, testing agents such as calcium chloride for control of dust and surface erosion. The field work ranged over most States. As the staff was greatly reduced due to enlistments there was little opportunity for normal surveys.

(2) Surveys in South Australia.

As early as 1943 plans began to be made for post-war land settlement in South Australia both in irrigation and rainfall areas. The first unit examined was in the Hundred of Wanilla on Eyre Peninsula aggregating 40 square miles. This was followed by a number of small units both in the Murray Valley and in the South-East of the State. A large area was begun in 1945 on Kangaroo Island covering 180 square miles over the central plateau region of the island. This was the first of five units proposed for post-war settlement on the island and was regarded as a test case. The area included an experimental block with a record of five years' development, but as a further precaution surveys were made of three old established properties to the north. As a result of the surveys and correlations from it, the area has been approved for development and settlement.

In 1945 a number of new irrigation sites were examined along the Murray River. An extension of 3,000 acres from the Waikerie settlement was broadly surveyed, a unit of 8,000 acres near Lyrup as well as one of about 2,000 acres in the Renmark district were mapped in that district in detail. A thorough combing of the river high land for potential irrigation areas was made so that it is thought no material area, within the 150 feet pumping lift, of suitable soil and topography was omitted. There is not a great expansion possible in irrigation development under the standards adopted. Further attention was paid to the Loxton area originally surveyed in reconnaissance in 1941. The intensive survey was carried through in 1945 to 1947 and the final map is accepted as accurate. This map has been used as the base for design of subdivision into farms of between 20 and 30 acres, for the distribution of specific plantings, for the use of spray and furrow irrigation and for the delineation of unsuitable areas.

From time to time surveys or inspections have been made of areas in the South-East of South Australia for settlement of servicemen. The most important unit has been the virgin swamp known as Eight Mile Creek on the coast south of Mt. Gambier on which some intensive soil investigations were conducted, combined with a botanical study of the natural vegetation by the University of Adelaide.

In 1946 a comprehensive study was commenced of the soils of the Northern marginal lands extending from Orroroo to Hawker east of the Flinders Range in an elongated zone of about 2,500 square miles. The area was first covered in reconnaissance. The project was three-sided and conducted in association with the Soil Conservation Section of the Department of Agriculture. The objectives were first, a pedological study of the transition from red brown earths to desert loams and to brown or grey solonized soils of the shrub steppe (mallee) formation and with particular attention to the nature of the desert loam group; second an assessment of the erosion position over the whole area and in detail over a selected portion; third, a correlation of land use with the soils and erosion. The work was under the direction of the Division of Soils which was wholly responsible for the pedology and conducted the erosion survey with the aid of a soil conservation officer; the land use study was carried on by the Departmental officer. In the first year the reconnaissance defined the problems, mapped the general distribution of the zonal soil groups, and selected an area for detailed erosion study. In 1947 the survey of the selected area of

350 square miles was begun and partially completed. Aerial photographs were used exclusively as base maps as for all other larger unit surveys. The pedology of the Northern marginal lands zone has proved exceptionally interesting and it is hoped a much clearer knowledge of the desert loam group and the occurrence of red brown earths under low rainfall conditions of 13 inches will result.

During the period under review it has become apparent that the accumulation of information from the surveys of the past two decades is providing critical data for pedogenetic studies and understanding of the nature and origin of soils. The field work has borne fruit in a number of fundamental papers on pedogenesis, particularly those dealing with the effect of post-Miocene climate and geology on soils of southern Australia, on the development of soils on dissected laterite areas and the inter-relationship in effect of soil forming factors on soil morphology.

A summary of the total area surveyed in South Australia from 1943 to 1947 is in the following table:

SURVEYS IN SOUTH AUSTRALIA, 1943–47.

Irrigation Areas.	Rainfall Area.		
Intensive.	Detailed.	Broad scale.	Reconnaissance.
42 square miles	20 square miles	281 square miles	2,570 square miles

(3) SURVEYS BEYOND SOUTH AUSTRALIA.

The activities in the field in States other than South Australia have been extensive, and in 1947 included for the first time Queensland. Surveys of reconnaissance and detailed types and numerous inspection trips in connection with post-war land settlement have been conducted from the regional centres at Canberra, Deniliquin, Hobart and Perth. It is not intended to deal here with all the field investigations but only some of particular importance.

In New South Wales there are four units deserving comment: the Lismore district, Hunter Valley, Riverina and Coomealla.

(i) The Lismore survey which began in 1947 centred round a reputed decline in fertility of the red basaltic soils. This survey involved a pedological and chemical study of the red loam soil group and its relation to other soil derivatives of a black or brown colour occurring on basalt in the district. The latter apparently have maintained their productivity.

(ii) The Hunter Valley area began in 1946 as a survey of river flat soils to be developed intensively under irrigation and in 1947 extended to the adjacent hill country which proved of particular pedological interest. The survey has been tied in with mineralogical analysis of the sand fraction to ascertain the geological relationships of the soils and the whole project has opened up a new line of investigation for the Division.

(iii) The Riverina soils have long been under examination and ideas on their classification and the significance of structure in the profile have gradually crystallized. The region is being mapped in reconnaissance over the whole plain south of the Lachlan River and west of the dividing range.

(iv) The Coomealla unit deserves mention because it represents one of the largest undeveloped areas along the Murray River with claims to irrigation dvelopment under horticulture. The pattern and nature of the soils is very promising for future settlement.

In Victoria little was done beyond a proposed irrigation area for returned servicemen in the vicinity of Nathalia. More reconnaissance mapping has been done over the Goulburn and Murray Valleys to link with the Riverina survey. In Tasmania important units were surveyed on the north-west coast, the north-east coast and in the midlands and Launceston basin. The north-west coast with its undeveloped heath plains and virgin swamps of great size offers one of the future opportunities for intensive development of Crown land. The coastal plain of the north-east coast is a similar virgin area with unknown potential requiring study.

The Western Australian surveys were located in the high rainfall zone in the south-west on the poor soils of lateritic origin. Extensive areas are in process of examination and at present about 2,000 square miles have been covered in broad scale survey.

North Australia has been largely neglected as a scientific study. In 1946 the first large scale concerted attack was made on this territory with a combined team of workers from the Divisions of Plant Industry and Soils of the Council for Scientific and Industrial Research. In that year 30,000 square miles were covered in the Darwin-Katherine region and in 1947 a preliminary reconnaissance of the Barkly Tableland carried through. This work is planned to go on for a further three years in the North.

A summary of the areas surveyed beyond South Australia is given in the following table:

SURVEYS IN AUSTRALIA OUTSIDE SOUTH AUSTRALIA, 1943–47.

Irrigation areas.		Rainfall area.		
Intensive.	Reconnaissance.	Detailed.	Broad scale.	Reconnaissance.
140 square miles	1,453 square miles	853 square miles	2,000 square miles	30,820 sq. miles

3. SOIL CHEMISTRY SECTION.

With the increased activities of the Soil Survey Section the number of samples of type soils received in the laboratory for routine descriptive analyses has shown a big increase to about 1,500 samples per year. Mechanical analysis, pH, and soluble salts are done on most of these samples, while determinations of nitrogen, organic carbon, phosphoric acid, calcium carbonate and exchangeable cations are made on selected samples in the type profiles. In special cases other analyses, such as more detailed studies of the gravel, sand or clay fractions may be required. In addition to these type samples a large number of individual samples has been examined, including soils for soluble salts and reaction, clays for silicate analysis and gypsum deposits for calcium sulphate. During the war years soil samples were forwarded from the sites of Army farms and advice was given on the suitablity of these soils for fresh vegetable production.

A mobile laboratory unit was established and used in 1947 to assist in a soil and fertility survey of an area of red basaltic soils in the Northern Rivers District of New South Wales. After reconnaissance of the district sixteen areas of about 20 acres each, typical of the red basaltic soils and the more important associated soils were selected for detailed examination. Each of these areas was sampled on a regularly spaced grid system, surface (0–3″) and sub-surface (3–9″) samples being collected, usually at 2 chain intervals over the whole area. Soil reaction values were determined on all of these samples in the mobile laboratory and a proportion of the samples were brought back for more detailed examination, including phosphate studies, and determinations of nitrogen, carbon, exchangeable cations and exchange capacity. The latter determinations are being carried out at the headquarters laboratories of the Division. The soil reaction studies in the mobile laboratory disclosed considerable variation in soil pH from place to place in the areas sampled. No single sample could be taken to represent with any certainty an area of more than a few square yards. In some cases adjacent sampling sites showed differences of up to 1 pH unit. One small area sampled on a closely spaced grid at 4 yard intervals showed frequent variations of 0·5 pH unit between adjacent samplings. More detailed studies of the exchange properties of the colloids are in progress seeking to account for these variations in reaction in apparently uniform areas of soils.

A similar detailed pH survey of the Field Station of the Division of Animal Health and Production at Barooga, New South Wales, and an adjacent property was carried out to assist in the study of soil factors associated with the incidence of toxaemic jaundice. Here again considerable variation in soil pH within a comparatively small space was noted. On the basis of the survey, sites were selected for regular samplings to study any seasonal variation in soil reaction.

Other laboratory work associated with the toxaemic jaundice investigations included the examination of the soils collected in the survey of representative properties in the enzootic area. Toxaemic jaundice occurs in sheep as the result of excessive storage of copper by the grazing animal. Except for one area, where copper bearing minerals were known to occur, spectrographic examination of the soils showed that they were not unduly high in copper. A pot experiment was carried out to determine the effect of soil reaction on the uptake of copper and molybdenum by three of the pasture species (*Medicago denticulata*, *Erodium sygnorum*, and *Hordeum leporinum*) commonly found at Barooga. The copper and molybdenum of these plants growing on Barooga soil, the acidity or alkalinity of which was adjusted to give a series of reactions between pH 4·8 and 8·4, were determined and compared with that of plants growing on Urrbrae loam under similar conditions. The results confirmed an experiment that none of these plants absorbed significantly greater amounts of copper from the Barooga soil than they did from Urrbrae loam. Increase of acidity tended to increase the availability and uptake of copper from Urrbrae loam, but no similar increase was noted for Barooga soil within the range of acidities examined. The importance of soil reaction in controlling the availability and uptake of molybdenum was clearly demonstrated. Acidification of both soils reduced the availability, while the uptake from those soils made alkaline was many times that from the control soils. Molybdenum is thought to

be of significance because it controls the ingestion and storage of copper by the grazing animal.

A further project carried out in conjunction with the toxaemic jaundice investigations was a survey of subterranean clover growing throughout the Adelaide Hills and the South-East of South Australia. Samples from well-established clover pastures from thirty-two localities were collected at the flowering stage and examined for copper and molybdenum. Copper in the dry matter varied from 1·0 to 18·1 p.p.m., while molybdenum varied much more widely from 0·01 to 2·08 p.p.m. The amount of molybdenum in the plants showed a fair correlation with soil pH; the highest amounts of molybdenum were found in plants growing on more alkaline soils. There was no evidence of any correlation between copper in the plant and soil reaction. Samples collected in the South-East contained less copper, but much more molybdenum than did plants from the Adelaide Hills. Work is being continued on these samples to determine the amounts of other trace elements present.

The development of spectrochemical methods of analysis has always been an important part of the Division's activities and much progress has been made. The arc method of excitation of soils and plant ash has been extensively studied, and factors affecting the sensitivity of detection and accuracy of determination of the different elements evaluated. A series of ironstone gravels derived from various soils was examined for the less common metallic constituents. These gravels resulted from the concentration of iron in the profile. Along with the iron, gallium, molybdenum, lead, vanadium, and zinc appeared to be concentrated. Cobalt, copper, manganese, and nickel did not appear to be similarly concentrated.

A qualitative survey was made of the trace elements present in a range of phosphate rocks from a wide variety of sources and the superphosphates made from these rocks. In all the presence of 23 of the less common elements was noted in the rocks, with a maximum of 20 in any one sample. Considerable variations were noted in the amounts of some of the trace elements present, particularly in the lower grades of rock phosphate used during the war. The presence of some of these trace elements may be of importance in the interpretation of field experiments carried out with war-time superphosphate.

Much use of the spectrographic equipment was made during the war years and many analyses were carried out to assist other organizations. Among the types of material examined may be mentioned various minerals such as galena, bauxite and pyrites for trace constituents, tool steels for metals used in special alloys, also instrument jewels and coloured glasses. The equipment has also been used to assist other Divisions of the Council for Scientific and Industrial Research in preliminary surveys of trace element investigations. In this connection soil and plant samples from Western Australia and from Kangaroo Island have been examined to assist in dystokia investigations, soil and plant samples from field and pot experiments at Canberra, and numerous samples in connection with the toxaemic jaundice investigations.

Equipment for the Lundegärdh air-acetylene flame method of excitation was constructed and this method fully investigated. It was shown that the accuracy of the method was limited largely by the errors inherent in the photographic plate. From a study of the magnitude of these errors a suitable technique was developed for the determination of exchangeable calcium, magnesium, sodium, and potassium in soils free from calcium carbonate. The

method is now being extensively used for the routine determination of exchangeable cations in soils.

Laboratory methods for the chemical examination of soils have continued to receive attention. Modification of the butyl alcohol extraction methods for the determination of phosphorus has enabled the satisfactory colorimetric determination of the element even in the presence of excessive amounts of iron. Improvments have been effected in the glass electrode instrument used for soil pH determinations. Rapid methods for the mechanical analysis of soils have been further investigated, improvements effected in the technique of rapid dispersion, and a plummet balance satisfactorily applied to the determination of silt and clay fractions in many soils. The construction of an automatic sand washing machine has greatly facilitated routine determinations of mechanical analysis.

4. SOIL PHYSICS SECTION.

The main lines of investigation of this section have been in the fields of soil-water relations, soil structure, soil texture, the physical properties of soil colloids, and the engineering properties of soils.

1. Soil Texture.

The diagram drawn up in 1934 showing the relation of field descriptions of the texture of soils to their mechanical composition has been revised. The subdivision of the conventional triangular diagram into texture classes has been attempted on a more logical basis than hitherto. In addition, a new type of diagram has been developed in which the median size of the non-clay fraction is plotted against the clay content.

A new plummet method has been developed for measuring the density of soil suspensions. This allows a more critical measure of density to be made than is obtained with soil hydrometers. The instrument is more sensitive and allows measurements to be made corresponding to a limiting settling velocity which can be more accurately defined. Readings of density can be obtained as rapidly as with an hydrometer.

2. Soil Structure.

An investigation into the effect of a wheat fallow rotation on soil structure has been concluded. A significant decrease in water stable aggregates was found. The major part of the decline, which occurred over a period of up to twenty years, took place in the first five years of cultivation. Cultivation was also found to have caused a significant decrease in the nitrogen content. From statistical evidence it is improbable that, in the cases examined, the decline in nitrogen was itself the main immediate cause of the parallel decline in aggregation which resulted from cultivation. Work has been undertaken in co-operation with the Council's Research Station at Griffith (New South Wales) on changes in structure occurring under various reconditioning treatments of old irrigated orchard land.

Statistical investigations have been carried out on the relation of mechanical composition and nitrogen content to water-stable aggregation. It has been found that, in the soil studied, clay and silt content are both positively related to aggregation, but there was no significant relation for nitrogen content.

A procedure has been developed for examining soil structure in relation to a descriptive system being evolved by the Soil Survey Section. The resistance offered to the subdivision of large aggregates into smaller units and the hardness and size of these units are being examined. From data so far available, it appears that the descriptive method can be represented quantitatively.

3. Physical Properties of Soil Colloids.

An X-ray crystallograph has been obtained for studying the crystal structure of clays. It is intended to undertake a survey of clay minerals occurring in Australian soils, and a start will be made with the solonized brown soils (mallee) group. Methods are being examined and it is hoped to have a semi-quantitative method available for this work.

4. Movement of Water in Soils.

A spray infiltrometer has been developed for the study of the infiltration of water applied as a spray to soils. The spray infiltrometer was compared initially with commercial spray systems with regard to critical conditions of water entry into soils. It was found that, for given rates of irrigation, results for the two systems compared closely. This part of the work was carried out co-operatively with the Departments of Agriculture and of Engineering and Water Supply, South Australia. The rate of infiltration of water into soils of the proposed Loxton Irrigation Area, South Australia, was then investigated by the same means. The objects were to determine which soil types were suitable for spray irrigation and what rates of application of irrigation water could be safely assumed for design purposes of plant and layout. Infiltration characteristics of the same soil types were compared in non-irrigated and in irrigated sites to enable a forecast to be made of future trends in the rate of infiltration after an area has been developed for a number of years.

Comparisons have been made between infiltration measurements by the ring infiltrometer and the spray infiltrometer. It has been shown that in the soils examined the guard area of wetted soil around the test plot of the spray infiltrometer restricts lateral movement sufficiently to make the results comparable to those which would be obtained if a large area were wetted by spray irrigation. On the other hand, only 30 per cent. of water entering the same soils from a ring infiltrometer penetrates vertically. The lateral movement of 70 per cent. of the water away from the test column results in excessively high values for the infiltration capacity when the ring method is used. The ring method is nevertheless of great value as a relative measure of infiltration.

Investigations have been made into the water relations of soils of an area under survey by the Western Australian Government near the Ord River in the Kimberley district of north-western Australia. Infiltration measurements were carried out with officers of the Western Australian Department of Agriculture on the three major soil types. Measurements of available soil water and soil structure have also been made.

5. Retention of Water by Soils.

The pressure potential of soil water at field capacity has been found to be approximately ·—70 ergs per gram in sandy soils investigated at Waikerie and Loxton, South Australia. This value is much higher than that usually

accepted, but other work here and overseas has fully confirmed that it is of the correct order. The results at Waikerie were obtained from records of measurements with tensiometers supplied to the Department of Agriculture, South Australia. Pressure potential (or "tension") conditions in soil water while water is being applied at the surface are also being examined.

Details of methods which have been developed for constructing tensiometers have been published. Other instruments for studying the water content of soils by *in situ* measurements include gypsum blocks, whose electrical conductivity varies with water content. Work has begun on the investigation of this indirect method.

The measurement of water retention at low water content by means of the freezing point method was undertaken. It was found that the depression of freezing point of soil water at the permanent wilting percentage could be taken as corresponding to 1·5° C. The freezing point method is useful as an indirect method for determining the permanent wilting percentage.

6. Engineering Properties of Soil.

During the war a considerable amount of work was done in examining soil conditions at proposed sites for aerodromes in various parts of Australia. Arising out of this, the Division undertook a preliminary study for the first major soil-cement project in Australia. Investigations relating to this and subsequent projects demonstrated the importance of rapidity in processing soil-cement. Considerable losses in compressive strength were detected where there was a delay of one hour or more between wetting and compacting. The loss in strength was found to be mainly due to the corresponding loss in density and it could be largely overcome if the material was compacted to specified density by the expenditure of additional energy. From an examination of the effect of portland cement on soil, it was concluded that the cement does not materially alter the soil colloids, but reduces their influence by aggregating them together.

Other defence work included trials with waterproofing materials (resins in particular) as a means of stabilizing soils, and the use of calcium chloride to prevent dust on aerodromes. Soils for use in testing the mud-crossing ability of army vehicles were also examined.

With the increasing demand for housing at the conclusion of the war a new project was commenced relating to soil as a foundation material for houses. Soil maps have been prepared and the physical properties of soil described for various suburban estates in Adelaide, Melbourne, and Sydney. This work is being undertaken to assist architects of the Housing Commission of Victoria and the Housing Trust of South Australia in their design of foundations, which is varied according to the type of soil. General information is being built up on soils in the suburban areas at the same time.

An important part of this project is the study of moisture changes under houses and the soil movement resulting from this because of the shrinkage or swelling of the soil. Field installations of electrical moisture meters have been made. In the laboratory, swelling is being studied by measuring volume changes of soil clods. The field moisture studies are co-ordinated at a Sydney site with studies of experimental foundations being made by the Building Experiment Station, Department of Works and Housing, which is working on the question of foundation design.

A study has been made for the South Australian Department of Mines of the permeability, porosity, and compaction properities of soft rocks from a proposed metropolitan dam site. The physical properties of various soils have also been examined for the South Australian Department of Highways and Local Government.

5. SOIL BACTERIOLOGY SECTION.

Investigations of the Section have been entirely directed to the *Rhizobium* organism and growth of leguminous plants. The major study has been on the effect of molybdenum on the activity of *Rhizobium* and the comparative result on the plant. It was found that molybdenum as ammonium molybdate applied at the rate of 1 oz. per acre gave an equivalent effect to an adequate dressing of sulphate of ammonia. The pattern of nodulation of the plants varied with the molybdenum treatment and nitrogen fertilization both as total counts and distribution of the nodules. The positive change in nodulation was reflected in nitrogen content of leaves and stems. The early work was with subterranean clover, but it was also demonstrated with *Phaseolus lathyroides* grown under summer conditions using phosphorus, nitrogen, and molybdenum. The plants responded to all these when nodulated, but little response was obtained from molybdenum on uninoculated plants.

Work was begun on the effect of molydenum on *Clostridium butyricum,* which is known to be absent from soils deficient in this element.

Successful work was done in the growing of tropical legumes in a suitably heated cabinet and the isolation of effective strains of *Rhizobium* associated with them.

A further attempt on the effect of growing grass and clover in association confirmed previous studies. There is no beneficial effect during the growth cycle from the association as, with the periodical removal of the legume by clipping, the grasses showed typical nitrogen starvation. The positive effect of the association is the subsequent building up of the nitrogen status of the soil by decay of the legume following active nitrogen fixation during its growth.

The study of the life, growth, and longevity of *Rhizobium* spp. in liquid cultures under varying conditions of aeration was begun. The problem of resistance to drying and lyophilization under controlled conditions, and with respect to the activity of protective colloids, is linked with persistence of the organism in soils under degrees of desiccation.

As an aid to Commonwealth Food Control a course of testing of canned foodstuffs was undertaken in the latter war period to detect defects in processing and the liability of spoilage of consignments.

Throughout the review period a service of supplying legume cultures to South Australian farmers has been continued. The demand grew from 840 cultures in 1943 to 1,500 in 1947, indicating a much wider use of inoculation by farmers, particularly in the less fertile soils now being developed in better rainfall areas.

6. GUAYULE RUBBER.

In a previous section (page 28) have been reported the steps that were taken in the establishment of a number of areas of guayule (*Parthenium argentatum*) in South Australia. At the end of 1947, ten areas were under

observation, five of these being in the River Murray irrigation areas, and the remainder in diverse environments of natural rainfall and varying soil conditions.

A further variation was that some of the planting were grown from seed produced at Canberra as a result of an introduction of the plant into Australia some years before the current project was under contemplation. The remainder of the plantings are derived from seed imported from the United States specially for the project, derived from plants selected for a high content of rubber.

The plantings have made steady growth and the rubber content has been increasing. Intermittent irrigation in summer has had markedly favourable effects on the development of the plants. Towards the end of 1947 the plants raised from the original Canberra seed averaged 223 gms. at Monarto South under natural rainfall conditions, and 1,935 gms. at the Berri Government Orchard under irrigation. Plants from the selected American seed averaged 362 gms. at Thrington under natural rainfall, and 1,210 gms. at Loxton with three irrigations per annum.

The rubber content was 4·7 per cent. at Monarto South, 2·8 per cent at Berri, 9·6 per cent. at Trington, and 8·7 per cent. at Loxton. The advantage of using seed from selected plants is shown in these analyses. The maximum amount of rubber has been produced at Loxton, namely 105 gms. per plant.

Oenological Research

The oenological research, commenced at the Waite Institute in 1935, was carried out under the discipline of the University of Adelaide until October, 1945, when the Council for Scientific and Industrial Research assumed responsibility for the investigations. The Committee on Oenological Research, which consists of representatives of the Council for Scientific and Industrial Research, the University of Adelaide, the Federal Viticultural Council, and the Australian Wine Board, has continued since 1938 to exercise general supervision over the nature of the research carried out.

1. Sherry Investigations.

Since the beginning of 1943, the chief subject under investigation has been the use of the film-forming yeasts known as "sherry flor" in the maturation of Australian sherry. More particularly, the metabolism of these yeasts has been studied, for it has been found that a vigorous growth of the "flor," or yeast film, does not always impart to wine the desirable flavour and aroma referred to as "flor character".

When growing as a film on wine or other suitable media containing ethyl alcohol, the flor yeast oxidizes alcohol with the accumulation of acetaldehyde as an intermediate and the formation of acetyl methyl carbinol. However, vigorous growth in artificial media occurs only when another carbon source in addition to ethyl alcohol is included. Of the carbon sources used, glycerol, sugar in small amounts, lactate, malate, and tartrate have given the most vigorous film growth. In wines the fixed acids as well as the residual sugar

and glycerol are also attacked by the yeast film. Other changes which occur in wine under the influence of the yeast film are an increase in the concentrations of acetaldehyde and volatile esters, a decrease in volatile acidity, and the appearance of acetyl methyl carbinol. Although all of these changes influence the flavour or aroma of the wine, the predominating factor in the development of flor character seems to be the accumulation of acetaldehyde.

In some cases aldehyde accumulation and flor character development continue steadily to a high maximum which is maintained for weeks or months, while in others the aldehyde disappears rapidly after a slight initial accumulation and may or may not accumulate again after a prolonged period of film growth. The influence of various factors on the accumulation of acetaldehyde has been studied with growing cultures in wine and in artificial media, and also with suspensions of non-proliferating cells shaken with various substrates under different conditions.

It has been found that the course of aldehyde accumulation is influenced by a number of factors, which include the strain of yeast, temperature, air supply, and the composition of the medium. By adjusting the composition of artificial media a reasonable measure of control over the course of aldehyde accumulation in such media has been obtained, but less success has been achieved with wines up till the present and neither the course nor the extent of aldehyde accumulation and flor character development in wines can yet be controlled with any degree of certainty.

2. The pH Value of Wines.

Of the various methods available for determining the pH value of wine, the quinhydrone electrode system has been one of the most widely used, but an increasing number of glass electrode pH meters are now being used in wineries. Values obtained for the pH of wines by means of the glass and quinhydrone electrodes sometimes agree, but often differ by more than 0·1 pH unit. The effects of several constituents of wine on these electrode systems have been examined and it is concluded that, whereas the glass electrode values are essentially correct, the quinhydrone electrode, when used in wines, is subject to at least two sources of error. Alcohol causes the quinhydrone electrode to register low values, while reducing substances, such as sulphites and tannin, lead to high values. In most wines tested the alcohol error predominated and the quinhydrone electrode gave low values, but correct or near correct values were obtained with the quinhydrone electrode in some wines due to a compensation of errors. Neither the hydro-quinhydrone nor the quinoquinhydrone electrodes give more reliable results in wines than the regular quinhydrone electrode.

Papers Published by the Staff of the Council for Scientific and Industrial Research 1943-1947

Division of Soils

I. PEDOLOGY AND SOIL SURVEYS.

C. G. Stephens, J. G. Baldwin and J. S. Hosking. "The Soils of the Parishes of Longford, Cressy, and Lawrence, County Westmorland, Tasmania. 1. A Soil Survey of the Area. 2. Pot Experiments with Subterranean Clover on the Cressy Shaley Clay-loam." C.S.I.R. Bull. *150*. 1942. (Reprint 369).

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C. G. Stephens. "Pedogenesis following the Dissection of Lacteritic Regions in Southern Australia." C.S.I.R. Bull. *206*. 1946. (Reprint 505).

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V. MISCELLANEOUS.

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VI. DIVISIONAL REPORTS.

Since 1946 Divisional Reports in a regular series have been issued. They represent work which is in progress but not yet in the publication stage. The information may be useful to others or may be items of a type not suitable for publication due to their restricted interest or scope. In 1946, 22 such reports were issued, and in 1947, 35.

Oenological Research

J. C. M. Fornachon. "The pH of Wines." Ind. and Eng. Chem. *18*: 790. 1946. (Reprint 494).

Mineral Deficiencies Investigations

A. J. Anderson. "Double-compartment Pot Cultures for Studies in Plant Nutrition." Jour. C.S.I.R. *17*: 144–50. 1944. (Reprint 417).

A. J. Anderson. "An Automatic Irrigator Actuated by a Soil-Moisture Tensiometer." Jour. C.S.I.R. *17*: 151–6. 1944. (Reprint 419).

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Records of Field Experimental Work

LIST OF FIELD EXPERIMENT RECORDS.

1. Permanent Rotation Experiment, 1926–47.
2. Influence of Grazed and Harvested Forage Crops on the Yield of Temporary Pasture and Wheat in Four-course Rotations, 1937–47.
3. Effect of Phosphate, Nitrogen and Lime on the Yield of Wheat, Oats, Barley and Peas in Four-Course Rotations, 1940–47.
4. Time and Rate of Seeding Trial with Field Peas, 1944–47.
5. Yield Trials of New Crossbred Wheats at Waite Institute, 1943–47.
6. Yield Trials of New Crossbred Wheats at Saddleworth, 1943–47.
7. Yield Trials of New Crossbred Wheats at Pallamana, 1944–47.
8. Yield Trials of Barley Varieties, 1943–44.
9. Yield Trials of Pea Varieties, 1943–47.
10. Flax Variety Trials, 1944–47.
11. Safflower Variety Trials, 1944–47.
12. Influence of Top-dressing on the Yield and Carrying Capacity of Natural Pasture, 1925–47.
13. Effect of Superphosphate and Surface Cultivation on the Yield of a Seeded Pasture 1937–47.
14. Influence of Management on Livestock Production at the Waite Institute and Kybybolite.
15. Yield and Composition of Sown Pastures with Differential Fertilizer Treatment under Irrigation on Heavy Lignum-Box Flats at Renmark, South Australia, 1944–47.

FORM AND TREATMENT OF TABLES.

In the succeeding tables the summarized records of the field experimental work carried out by the Waite Institute since its inception, and given in previous reports, have been supplemented by the data recorded from 1943–47.

A summary of the design and treatments employed appears at the head of each table.

Wherever possible, the data have been statistically analysed and the standard error values included. Two of the permanent field experiments (1 and 12) were commenced in 1925, prior to the adoption here of modern field designs, and no replication of treatment occurs in any one year.

The following is an example of one type of table:

Mean yields of pasture in cwt. per ac. ±*1·555.*

	Rate of superphosphate: cwt. per ac.				
Cultivation	0	1	2	3	Mean ± 0·777
C_0	40·86	48·85	46·88	46·98	**45·89**
C_1	42·17	45·52	49·37	48·24	**46·33**
Mean ± 0·797	**41·52**	**47·18**	**48·12**	**47·61**	**46·11**

The numbers in ordinary type are the mean yields of the treatments indicated at the headings of the columns and the left-hand margins of the rows. Thus 40·86 is the yield of pasture in cwt. per acre averaged over all plots not cultivated and receiving no superphosphate. The numbers in heavy type denote more general averages. Thus **45·89** is the yield in cwt. per acre averaged over all rates of superphosphate of the plots receiving no cultivation. The general mean of all treatments is **46·11** cwt. per acre.

The standard errors (prefaced by the sign ±) are given in conjunction with the means. In testing the difference between two quantities having the same standard error, it may be assumed that the difference is significant if it exceeds three times that standard error. Thus the difference between 45·89 and 46·33 is 0·44 which is not as great as three times 0·777 so cultivation has no significant effect. The differences between the means for 0 and 1, 1 and 2, 2 and 3, cwt. per acre superphosphate are 5·66, 0·94 and 0·51 respectively. Only the first of these, 5·66, exceeds three times 0·797 so superphosphate at 1 cwt. per acre causes a significant increase in yield but further applications have no additional effect.

The areas of plots given in the tables denote areas at harvest. Unless otherwise specified, the experiments have been conducted at the Waite Institute.

1. PERMANENT ROTATION EXPERIMENT, 1926-47.

Effect of different crop rotations on the yield of wheat.

Variety of crop and seed rate per ac.; Sepoy wheat (1926-34) and Seewari (1935-47), 80–90 lb.; Early Burt oats, 60–70 lb.; Prior barley, 70–80 lb.; White Brunswick peas, 120–150 lb.; Wimmera rye-grass (1926–45), 10–15 lb. — (1946–47) Fulghum oats, 40 lb. + Wimmera rye-grass, 3 lb.; Sudan grass, 10-15 lb.

Basal dressing of superphosphate containing 20 lb. of P_2O_5 per ac. (approximately 97 lb. of 45 per cent. superphosphate).

Design: 31 plots, grouped in 12 rotations, so that each course of the 12 rotations is represented every year. Rotations as per table.

Area of each plot = 1/7th ac. (1926-37) $1/7_{\cdot 619}$ ac. (1938-47).

(a) Total yields of crop and pasture in cwt. air-dry material per ac., Sudan grass in cwt. green fodder per ac.

Rotation	Crop	Mean 1926–42	1943	1944	1945	1946	1947	Mean 1926–47
1	Fallow							
	Wheat	51·15	70·27	35·19	58·71	41·92	30·56	50·28
2	Peas	30·75	37·62	17·14	27·61	20·86	34·25	30·01
	Wheat	40·56	44·08	32·01	32·53	17·05	20·82	38·00
3	Fallow							
	Wheat	58·14	84·56	46·49	79·72	54·39	42·04	58·89
	Rye-grass	27·29	39·24	22·21	33·94	43·54	49·59	29·79
4	Fallow							
	Wheat	57·45	64·08	48·59	75·96	42·33	42·04	56·80
	Oats	42·28	33·95	18·54	54·29	14·19	40·27	40·00
5	Fallow							
	Wheat	60·66	93·13	48·44	87·18	57·22	52·65	62·27
	Peas	35·55	42·24	22·86	37·62	40·15	45·37	36·03
6	Fallow							
	Wheat	60·34	71·22	41·35	64·88	44·23	41·84	58·61
	Barley	45·84	48·84	21·07	29·40	31·56	39·46	43·16
7	Wheat	26·32	31·22	13·11	13·65	26·38	27·89	25·44
8	Peas	37·61	49·05	19·05	39·05	37·55	53·81	38·08
	Wheat	47·50	65·71	37·20	44·10	47·49	33·06	47·05
	Oats	37·50	33·95	13·25	42·58	15·74	56·46	36·34
9	Peas	37·58	51·02	24·29	38·37	41·98	48·44	38·32
	Wheat	49·84	75·51	37·80	50·69	44·87	40·75	49·86
	Barley	44·69	46·26	22·09	37·00	36·12	55·51	43·49
10	Fallow							
	Wheat	66·62	100·27	53·00	91·74	60·85	59·47	68·08
	Oats	50·58	44·56	23·61	52·21	45·05	70·07	49·79
	Rye-grass	31·58	33·26	19·02	29·86	42·69	57·86	32·76
11	Sudan grass	25·15	7·62	29·52	32·86	28·90	Failure	23·93
	Wheat	49·00	71·50	36·28	26·86	47·30	44·08	48·13
12	Fallow							
	Wheat	55·84	80·27	37·00	60·91	54·46	42·28	55·64

(b) Grain yields in bushels per ac.

Rotation	Crop	Mean 1926–42	1943	1944	1945	1946	1947	Mean 1926–47
1	Fallow							
	Wheat	**34·53**	**47·90**	**28·01**	**44·97**	**32·73**	**15·94**	**34·39**
2	Peas	20·40	27·62	15·68	20·06	14·55	23·39	20·37
	Wheat	**27·35**	**32·48**	**27·61**	**24·35**	**17·80**	**11·72**	**26·31**
3	Fallow							
	Wheat	**38·87**	**61·65**	**38·08**	**58·83**	**37·85**	**24·56**	**40·08**
	Rye-grass*							
4	Fallow							
	Wheat	**35·91**	**37·52**	**37·81**	**55·16**	**24·94**	**20·00**	**35·72**
	Oats	45·53	33·81	26·26	59·47	—	43·28	42·58
5	Fallow							
	Wheat	**38·99**	**65·52**	**36·73**	**60·42**	**45·17**	**24·95**	**40·71**
	Peas	26·50	31·05	21·40	24·79	—	36·82	25·66
6	Fallow							
	Wheat	**38·91**	**44·06**	**33·15**	**43·52**	**27·00**	**19·94**	**37·69**
	Barley	46·65	47·43	24·98	28·02	22·10	43·62	43·60
7	Wheat	**15·20**	**22·98**	**10·78**	**6·94**	**11·74**	**12·58**	**14·70**
8	Peas	28·78	35·90	18·29	32·03	28·02	40·63	29·28
	Wheat	**31·44**	**48·32**	**29·43**	**29·87**	**36·65**	**19·08**	**31·72**
	Oats	38·47	31·24	16·57	50·74	—	61·15	36·98
9	Peas	29·35	38·60	21·97	32·35	28·78	37·90	29·94
	Wheat	**33·76**	**56·35**	**31·02**	**34·23**	**31·52**	**24·67**	**34·17**
	Barley	45·20	44·49	26·76	36·54	26·70	61·80	43·85
10	Fallow							
	Wheat	**43·79**	**70·32**	**42·98**	**63·19**	**35·05**	**31·49**	**44·88**
	Oats	55·27	45·43	34·42	59·76	38·78	78·91	54·40
	Rye-grass*							
11	Sudan grass*							
	Wheat	**33·72**	**51·90**	**29·10**	**17·81**	**33·81**	**23·36**	**33·15**
12	Fallow							
	Wheat	**37·92**	**54·22**	**29·10**	**40·85**	**40·01**	**21·55**	**37·75**

* Yields (cwt. per ac.) in previous table.

2. INFLUENCE OF GRAZED AND HARVESTED FORAGE CROPS ON THE YIELD OF TEMPORARY PASTURE AND WHEAT IN FOUR-COURSE ROTATIONS, 1937–47.

Rotations:

A	B	C	D	E
Fallow	Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat	Wheat
Peas	Clover	Barley	Oats	Fallow
Pasture	Pasture	Pasture	Pasture	Wheat

Variety of crop and seed rate per ac.:
Sepoy Wheat, 80–90 lb., Sepoy Wheat (1937–45) and Seewari Wheat (1946–47); Cape barley, 70–80 lb.; Mulga oats, 60–70 lb.; White Brunswick peas, 120–150 lb.; Clover mixture (Mt. Barker subterranean clover, Dwalganup subterranean clover, and barrel medic), 10 lb. per ac. each; Wimmera rye-grass, 10 lb. per ac. as pasture.

Basal fertilizer dressing: superphosphate to all crops including pasture at 2 cwt. per ac. (1937–41), at 1 cwt. per ac. (1942–47).

Forage crop treatment: G = grazed. H = harvested.

Design: 60 main plots in 4 groups of 15 plots, each representing one course of the rotation. The groups of 15 plots are divided into 3 randomized blocks of 5 plots, each representing a different rotation. Each plot is subdivided into halves; on one the forage crop is grazed, and on the other it is harvested.

Area of main plots = $\frac{1}{6 \cdot 94}$ acre.

(a) Yields of forage crops (air-dry).

	A Peas.			B Clover.		C Barley.			D Oats.		
	G	H		G	H	G	H		G	H	
Year.	(cwt.)	(cwt.)	(bush.)	(cwt.)	(cwt.)	(cwt.)	(cwt.)	(bush.)	(cwt.)	(cwt.)	(bush.)
Mean 1937–42	49·40	43·62	34·01	29·45	25·76	21·02	22·78	23·64	18·00	21·08	23·34
1943	51·51	41·92	24·58	22·76	44·25	24·89	35·22	37·47	34·45	30·55	32·35
1944	21·01	14·73	13·71	8·86	4·97	12·41	10·86	10·05	11·56	9·79	12·32
1945	47·47	28·44	26·23	12·76	14·13	15·68	15·66	16·84	17·78	20·27	22·17
Mean 1937–44	**46·11**	**39·80**	**30·29**	**26·04**	**25·47**	**20·42**	**22·84**	**23·67**	**19·25**	**20·85**	**23·09**
Mean ±	1·585		1·511	2·181		1·271		1·576	1·719		0·863

(b) Yields of temporary pasture (air-dry) in cwt. per ac.

	A After peas.		B After clover.		C After barley.		D After oats.	
Year.	G	H	G	H	G	H	G	H
Mean 1938–42	51·37	34·15	24·09	20·75	17·95	12·07	14·73	10·82
1943	57·72	37·14	24·47	16·80	13·90	8·48	9·81	9·74
1944	41·72	29·29	29·29	17·37	17·39	10·98	17·02	8·57
1945	54·52	30·22	16·29	14·64	13·64	12·19	15·04	13·26
Mean 1938–45	**51·35**	**33·43**	**23·81**	**19·07**	**16·84**	**11·50**	**14·44**	**10·71**

Means (1938-45) ± 0·716.

	After peas.	After clover.	After barley.	After Oats.	Mean ± 0.320
Grazed	51·35	23·81	16·84	14·44	26·61
Harvested	33·43	19·97	11·50	10·71	18·68
Mean ± 0·673	**42·39**	**21·44**	**14·17**	**12·58**	22·65

(c) Yields of wheat in bushels per ac.

Year.	A After peas. G	A After peas. H	B After clover. G	B After clover. H	C After barley. G	C After barley. H	D After oats. G	D After oats. H	E After fallow-wheat. G	E After fallow-wheat. H
Mean 1940–42	47·81	46·90	47·48	45·19	43·73	41·01	43·91	40·58	43·64	41·28
1943	51·44	52·59	40·51	46·54	40·77	44·90	40·06	40·65	30·94	31·84
1944	35·77	27·17	30·64	28·04	31·34	27·29	29·99	28·12	15·90	12·85
1945	54·49	48·18	50·13	43·97	45·19	39·04	41·72	36·35	37·35	33·54
1946	32·30	30·66	25·96	28·00	25·71	25·02	28·22	26·56	23·05	20·02
1947	30·51	33·44	28·52	31·03	27·71	30·22	27·60	28·68	23·36	26·25
Mean 1940–47	**43·49**	**41·59**	**39·77**	**39·15**	**37·74**	**36·19**	**37·42**	**35·26**	**32·69**	**31·05**

Means (1940-47) ± 0·475.

	After peas.	After clover	After barley.	After oats.	After fallow-wheat.	Mean ± 0.212
Grazed	43·49	39·77	37·74	37·42	32·69	**47·78**
Harvested	41·59	39·15	36·19	35·26	31·05	**45·58**
Mean ± 0·349	**42·54**	**39·46**	**36·97**	**35·87**	**31·87**	**46·68**

3. EFFECT OF PHOSPHATE, NITROGEN AND LIME ON THE YIELD OF WHEAT, OATS, BARLEY AND PEAS IN FOUR-COURSE ROTATIONS.

Rotations:

A	B	C	D
Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat
Peas	Oats	Barley	Wheat
Pasture	Pasture	Pasture	Pasture

Variety of crop and seed rate per ac.:

Seewari Wheat, 80–90 lb.; Mulga oats, 60–70 lb.; Prior barley, 70–80 lb.; White Brunswick peas, 120–150 lb. Pasture: Wimmera rye-grass, 3 lb. + Mt. Barker subterranean clover, 6 lb. + Dwalganup subterranean clover, 6 lb. (1940–43); Wimmera rye-grass, 3 lb. + Mt. Barker subterranean clover, 3 lb. + Bacchus Marsh subterranean clover, 3 lb. + Dwalganup subterranean clover, 3 lb. + barrel medic, 3 lb. (1944–47).

Fertilizer treatments:

Superphosphate: P_0 = nil, P_1 = 1 cwt. per ac., P_2 = 2 cwt. per ac.
Sulphate of ammonia: N_0 = nil, N_1 = 1 cwt. per ac., N_2 = 2 cwt. per ac.
Lime (calcium hydroxide): L_0 = nil, L_1 = 2½ cwt. per ac., L_2 = 5 cwt. per ac.
All combinations of superphosphate, sulphate of ammonia, and lime are applied to the cereal crops and peas. The pastures receive no fertilizer.

Design: 432 plots, in 4 groups of 108 plots, one group to each rotation. Each of these groups of 108 plots is subdivided into 4 sections of 27 plots, and these sections represent the four courses of each rotation in every year. Each section of 27 plots is subdivided into 3 randomized blocks of 9 plots for the application of the fertilizer treatments. This subdivision confounds a pair of degrees of freedom for second order interaction with soil differences.

Area of a single plot = 1/77th acre.

Yields of grain in bushels per ac. (1940-47).

Rotation A.

Wheat.

	Mean of all lime. N_0	N_1	N_2	Mean of all nitrogen. L_0	L_1	L_2	Mean	Mean of all phosphate.	N_0	N_1	N_2
P_0	38·93	39·48	40·76	38·59	40·68	39·91	**39·72**	L_0	42·37	41·87	42·27
P_1	45·40	44·50	44·61	43·58	46·14	44·69	**44·84**	L_1	43·85	43·79	43·91
P_2	44·72	45·01	44·42	44·25	44·73	45·17	**44·72**	L_2	42·82	43·44	43·61
Mean	**43·01**	**43·00**	**43·26**	**42·17**	**43·85**	**43·26**	**43·09**				

Peas.

P_0	36·65	36·24	34·73	35·03	36·55	36·04	**35·87**	L_0	40·62	39·46	39·23
P_1	43·66	42·98	43·42	43·07	43·52	43·46	**43·35**	L_1	41·48	42·21	40·44
P_2	42·79	43·91	41·90	41·21	44·04	43·34	**42·87**	L_2	41·00	41·46	40·38
Mean	**41·03**	**41·04**	**40·02**	**39·77**	**41·37**	**40·95**	**40·70**				

Rotation B.

Wheat.

P_0	34·86	34·39	36·22	34·40	35·37	35·70	**35·16**	L_0	38·01	39·33	41·18
P_1	41·24	42·27	44·51	41·80	42·96	43·26	**42·67**	L_1	40·70	40·00	40·99
P_2	42·28	43·20	44·59	42·32	43·35	44·40	**43·36**	L_2	39·67	40·52	43·16
Mean	**39·46**	**39·95**	**41·78**	**39·51**	**40·56**	**41·12**	**40·40**				

Oats.

P_0	47·14	57·74	63·63	55·36	56·13	57·03	**56·17**	L_0	45·87	60·54	68·85
P_1	47·27	61·14	71·53	61·32	60·24	58·39	**59·98**	L_1	45·70	58·87	69·72
P_2	43·82	59·82	71·17	58·58	57·93	58·30	**58·27**	L_2	46·66	59·30	67·76
Mean	**46·08**	**59·57**	**68·78**	**58·42**	**58·10**	**57·90**	**58·14**				

Rotation C.

Wheat.

P_0	33·12	34·15	35·55	34·35	33·56	34·92	**34·28**	L_0	39·08	39·54	40·22
P_1	41·97	41·13	43·52	41·28	42·98	42·37	**42·21**	L_1	38·09	39·72	41·36
P_2	41·33	43·59	43·41	43·21	42·63	42·49	**42·78**	L_2	39·27	39·61	40·91
Mean	**38·81**	**39·63**	**40·83**	**39·61**	**39·72**	**39·93**	**39·75**				

Barley.

P_0	36·98	41·00	45·53	40·56	41·70	41·25	**41·17**	L_0	34·14	42·61	49·04
P_1	34·86	46·72	52·05	43·12	44·94	45·56	**44·54**	L_1	36·12	44·18	49·60
P_2	35·20	42·81	49·71	42·10	43·26	42·36	**42·57**	L_2	36·79	43·75	48·64
Mean	**35·68**	**43·51**	**49·09**	**41·93**	**43·30**	**43·06**	**42·76**				

Rotation D.

Wheat.

P_0	36·81	35·93	37·12	35·48	36·98	37·41	**36·62**	L_0	40·52	41·74	42·34
P_1	42·63	44·23	45·03	44·53	43·58	43·78	**43·97**	L_1	42·48	42·13	41·89
P_2	44·63	45·97	44·84	44·59	45·95	44·91	**45·15**	L_2	41·07	42·27	42·76
Mean	**41·36**	**42·05**	**42·33**	**41·53**	**42·17**	**42·03**	**41·91**				

Wheat (Stubble-sown).

P_0	26·25	27·38	29·33	27·44	27·76	27·76	**27·65**	L_0	26·62	29·77	33·75
P_1	26·37	31·80	36·45	31·91	30·25	32·46	**31·54**	L_1	25·74	29·96	33·87
P_2	25·84	31·64	35·93	30·78	31·55	31·08	**31·14**	L_2	26·11	31·09	34·11
Mean	**26·15**	**30·27**	**33·91**	**30·04**	**29·85**	**30·44**	**30·11**				

Yields of temporary pasture (oven-dry) in cwt. per ac.

Means (1940-47).

	N_0	N_1	N_2	P_0	P_1	P_2	L_0	L_1	L_2	Mean.
Rotation A	34·37	34·38	35·08	31·64	34·66	37·43	33·30	35·01	35·42	**34·58**
„ B	22·54	21·63	21·35	19·43	22·07	24·01	20·87	22·01	22·63	**21·84**
„ C	28·61	27·40	29·21	24·72	28·49	32·02	26·05	28·09	31·08	**28·41**
„ D	28·56	27·28	28·27	24·52	28·97	30·61	26·55	28·55	29·00	**28·04**
Mean	**28·49**	**27·67**	**28·48**	**25·08**	**28·55**	**31·02**	**26·69**	**28·42**	**29·54**	

Standard errors for comparing means: N_0, N_1 and N_2; P_0, P_1 and P_2; L_0, L_1, and L_2.

Wheat	±	0·415
Pasture	±	0·497
Peas	±	0·448
Oats	±	0·552
Barley	±	0·445
Wheat (stubble-sown)	±	0·356

Standard errors for comparing rotations.

Wheat	±	0·972
Pasture	±	1·819

Results of Analyses.

Rotation	Wheat. A, B, C, D	Pasture. A, B, C, D	Peas. A	Oats. B	Barley. C	Wheat (stubble-sown). D
		Main effects.				
Factor						
N	***	*		***	***	***
P	***	***	***	***	***	***
L	**	***	*			
Cycle	***					
Season	***	***				
Rotation		***				
		Interactions.				
Factor						
P x N				***	***	***
P x L		**				
Cycle x P	***		***	*		**
Cycle x N				*	***	

* = significant at $P < \cdot 05$
** = significant at $P < \cdot 01$
*** = significant at $P < \cdot 001$

Yields of Total Produce in cwt. per ac. (1940-47).

Rotation A.

Wheat.

	Mean of all lime. N_0	N_1	N_2	Mean of all nitrogen. L_0	L_1	L_2	Mean	Mean of all phosphate.	N_0	N_1	N_2
P_0	55·87	57·82	61·40	57·63	59·31	58·15	**58·37**	L_0	63·31	63·77	66·29
P_1	67·76	67·71	70·11	66·79	70·29	68·51	**68·53**	L_1	64·19	66·85	67·88
P_2	66·66	69·66	70·71	68·93	69·32	68·79	**69·01**	L_2	62·79	64·58	68·06
Mean	**63·43**	**65·06**	**67·41**	**64·46**	**66·30**	**65·15**	**65·30**				

Peas.

P_0	43·95	44·04	44·47	42·37	45·28	44·80	**44·15**	L_0	48·72	50·11	51·40
P_1	53·55	54·94	56·08	54·21	55·12	55·24	**54·86**	L_1	52·42	53·35	52·06
P_2	56·00	57·90	54·73	53·65	57·44	57·55	**56·21**	L_2	52·35	53·42	51·82
Mean	**51·16**	**52·29**	**51·76**	**50·08**	**52·61**	**52·54**	**51·74**				

Rotation B.

Wheat.

P_0	47·27	48·80	51·75	48·51	49·16	50·16	**49·28**	L_0	54·44	58·13	62·05
P_1	59·02	62·12	67·12	61·85	63·04	63·37	**62·76**	L_1	57·48	58·07	61·48
P_2	61·48	64·07	68·49	64·27	64·84	64·94	**64·68**	L_2	55·85	58·79	63·83
Mean	**55·92**	**58·33**	**62·46**	**58·21**	**59·02**	**59·49**	**58·90**				

Oats.

P_0	40·78	51·51	58·78	50·29	49·67	51·10	**50·36**	L_0	40·46	54·99	64·80
P_1	41·03	54·92	67·02	55·04	54·43	53·49	**54·32**	L_1	39·76	52·71	65·41
P_2	39·42	54·62	68·25	54·91	53·77	53·52	**54·10**	L_2	41·02	53·36	63·83
Mean	**40·41**	**53·68**	**64·68**	**53·42**	**52·62**	**52·73**	**52·92**				

Rotation C.

Wheat.

P_0	43·87	46·53	50·03	47·56	45·43	47·43	**46·80**	L_0	55·35	56·66	59·84
P_1	59·37	60·49	65·09	60·47	62·79	61·69	**61·65**	L_1	53·44	57·46	60·47
P_2	60·39	64·64	65·46	63·80	63·15	63·54	**63·50**	L_2	54·85	57·54	60·28
Mean	**54·54**	**57·22**	**60·20**	**57·28**	**57·12**	**57·55**	**57·32**				

Barley.

P_0	33·06	37·23	42·66	37·22	37·76	37·97	**37·65**	L_0	30·72	40·03	47·14
P_1	31·68	44·04	50·21	40·63	42·18	43·11	**41·97**	L_1	32·45	41·03	47·26
P_2	31·87	40·52	48·19	40·03	40·79	39·77	**40·20**	L_2	33·45	40·73	46·66
Mean	**32·21**	**40·60**	**47·02**	**39·29**	**40·24**	**40·29**	**39·94**				

Rotation D.

Wheat.

P_0	49·34	50·00	52·42	49·69	51·44	50·62	**50·58**	L_0	57·05	59·84	62·71
P_1	60·47	64·30	67·20	64·18	64·33	63·46	**63·99**	L_1	59·77	60·72	62·22
P_2	63·70	66·71	68·04	65·75	66·93	65·78	**66·15**	L_2	56·69	60·46	62·72
Mean	**57·84**	**60·34**	**62·55**	**59·87**	**60·90**	**59·96**	**60·24**				

Wheat (stubble-sown).

P_0	33·13	35·69	39·29	35·78	36·52	38·81	**36·04**	L_0	33·58	39·12	46·47
P_1	32·99	41·85	50·32	42·06	40·26	42·84	**41·72**	L_1	32·71	39·24	46·46
P_2	32·41	41·91	50·87	41·33	41·64	42·21	**41·73**	L_2	32·24	41·09	47·54
Mean	**32·85**	**39·81**	**46·83**	**39·72**	**39·47**	**40·29**	**39·83**				

Standard errors for comparing means: N_0, N_1 and N_2; P_0, P_1 and P_2; L_0 L_1 and L_2.

Wheat	±	0·650
Peas	±	0·518
Oats	±	0·469
Barley	±	0·443
Wheat (stubble-sown)	±	0·472

Standard error for comparing rotations.

Wheat	±	1·166

Results of Analyses.

	Wheat.	Peas.	Oats.	Barley.	Wheat (stubble-sown).
Rotation	A, B, C, D	A	B	C	D
Main effects.					
Factor					
N	***		***	***	***
P	***	***	***	***	***
L		***			
Cycle	***				
Season	***				
Rotation	***				
Interactions.					
Factor					
P x N			***	***	***
P x L					
Cycle x P	***				**
Cycle x N			**	***	

* = significant at $P < \cdot 05$
** = significant at $P < \cdot 01$
*** = significant at $P < \cdot 001$

4. TIME AND RATE OF SEEDING TRIAL WITH FIELD PEAS, 1944–47.

Variety: White Brunswick.

Seed rate: 65, 95, 120 and 150 lb. per ac.

Superphosphate: Basal dressing of 1 cwt. per ac.

Time of sowing: Actual dates 1944, E = 16th May. M = 14th June. L = 11th July. In subsequent years the sowings were made in same three months as closely as practicable to the above dates.

Treatments: All combinations of seed rates and time of sowing.

Design: 4 randomized blocks of 3 main plots sown early mid-season and late respectively. Each main plot split into 4 subplots sown at 4 different seed rates. Total plots 48, complete replication, 4.

Area of main plot: $\frac{1}{7.86}$ ac.

Year.	Rate of Seeding. 65 lb.	95 lb.	120 lb.	150 lb.	Mean.
	Early sowing (May).				
1944	18·12	21·10	23·49	23·85	**21·64**
1945	31·11	26·20	25·72	22·92	**26·49**
1946	43·64	47·59	49·54	52·78	**48·39**
1947	61·67	64·03	53·19	52·69	**57·90**
Mean	**38·64**	**39·73**	**37·99**	**38·06**	**38·61**
	Mid-season sowing (June).				
1944	7·09	10·59	11·86	12·47	**10·50**
1945	20·16	24·58	23·02	26·67	**23·61**
1946	34·44	39·34	40·57	44·47	**39·70**
1947	64·41	66·72	65·85	63·60	**65·15**
Mean	**31·53**	**35·31**	**35·33**	**36·80**	**34·74**
	Late sowing (July).				
1944	1·64	2·25	2·49	2·80	**2·29**
1945	23·22	24·39	25·10	26·06	**24·69**
1946	24·80	27·81	34·16	36·89	**30·91**
1947	60·86	65·66	65·78	67·03	**64·83**
Mean	**27·63**	**30·03**	**31·88**	**33·20**	**30·69**
Means of times and years	**32·60**	**35·02**	**35·07**	**36·02**	**34·68**

5. YIELD TRIALS OF CROSSBRED WHEATS AND VARIETIES AT WAITE INSTITUTE, 1943–47.

A. Early sown plots. Superphosphate: 1 cwt. per acre.

	1943.	1944.	1945.	1946.	1947.	
Rainfall (seeding to harvest)	14·32	10·18	17·08	16·14	20·50	
	Strain No.	Mean yield (bush. per ac.).				Bushel Weight 1945.
((Gluyas x Hope) x Hard Federation) x Ghurka	(41–36)	37·7	40·5	37·1		65·7
Ranee 4H		37·2	37·6	40·4		65·4
(Gluyas x Hope) x Ghurka	(41–14)	35·4				
Ghurka		34·9	46·3	37·4	41·9	46·7	65·2
((Gluyas x Hope) x Hard Federation) x Ranee 4H	(41–48)	34·2		43·9			66·0
Nabawa x (Riverina x Hope)	(38–356)	33·9	40·0	40·2	41·2		63·0
Kenya Crossbred (late) x Ranee 4H ..	(41–119)	33·8					
Ghurka x (Pusa 4 x Ford)	(40–42)	32·4					
(Kenya Crossbred (early) x Ghurka) x (Gluyas x Hope)	(41–2)	30·7					
(Gluyas x Hope) x Nabawa	(39–248)	30·5					
Nabawa x (Nabawa x Hope)	(41–247)	30·2					
Nabawa x (Nabawa x Hope)	(40–246)	27·0					
(Gluyas x Hope) x Ghurka x Ghurka x Ghurka	(43–46)		42·7	36·3	42·1	46·8	64·8
(Gluyas x Hope) x Ghurka x Ghurka x Ghurka	(43–39)		42·1				
Kenya Crossbred (early) x Ghurka ..	(41–142)		41·9	33·8	38·0	38·4	66·5
Nabawa x (Riverina x Hope)	(40–242)		41·6				
(Gluyas x Hope) x Ghurka x Ghurka x Ghurka	(43–49)		40·8	35·7	40·6		64·9
(Gluyas x Hope) x Ghurka x Ghurka x Ghurka	(43–38)		40·0	31·0			66·0
Seewari			39·1	47·4	33·3	36·4	64·8
Quadrat				37·2	43·3	51·1	63·0
(Gluyas x Hope) x Ghurka x Ghurka x Ghurka	(43–47)			33·5			64·4
(Gluyas x Hope) x Ghurka x Ghurka x Ghurka	(43–37)			33·3			65·8
((Kenya Crossbred (early) x Ghurka) x (Gluyas x Hope)) x Ghurka x Ghurka	(43–62)			39·3			65·8
Kondut				37·3			65·2
((Kenya Crossbred (early) x Ghurka) x (Gluyas x Hope)) x Ghurka x Ghurka	(43–61)			35·8			65·4
(Gluyas x Hope) x Ghurka x Ghurka ..	(43–144)			35·7			66·3
((Kenya Crossbred (early) x Ghurka) x (Gluyas x Hope)) x Ghurka x Ghurka	(43–66)			34·9			66·0
Federation				34·3			65·2
((Ghurka x Hope) x Sepoy (Rust Resistant Selection)) x Ghurka	(43–246)			32·6			65·4
Gabo x Seewari x Seewari x Seewari ..	(45–825)				38·4		
Pindar					32·9		
Pinnacle					32·5	43·8	
Diadem						44·1	
Gabo x Seewari (5)	(45S–64)					42·2	
Gabo x Ghurka (4)	(2705)					40·9	
Gabo x Seewari (4)	(2683)					40·6	
Differences between two means, significant at 5 per cent. level (bush. per ac.)		2·9	4·4	3·7	4·1	4·3	

B. Mid-season sown plots. Superphosphate: 1 cwt. per acre.

		1944.	1945.	1946.	1947.	
Rainfall (seeding to harvest)		9·98	15·60	14·04	19·69	
	Strain No.	Mean yield (bush. per ac.)				Bushel Weight 1945
((Gluyas x Hope) x Hard Federation) x Ranee 4H	(41–48)	40·7		39·1		
Ranee 4H		39·4	45·6	23·5*		
				16·0†	29·1†	66·7
(Dindiloa x Ford) x Ghurka	(41–148)	37·1				
Ridley		37·0	48·2	35·8*	37·2*	66·8
(Gluyas x Hope) x Ranee 4H x Ranee 4H x Ranee 4H	(43–19)	36·9				
Kenya Crossbred (early) x Dundee	(40–109)	36·1	40·9	43·3†	41·7*	65·7
Nabawa x (Riverina x Hope)	(39–129)	36·0	40·5	40·1†		66·4
Nabawa x (Nabawa x Hope)	(40–254)	35·2	44·2	39·0*		65·8
Kenya Crossbred (early) x Dundee	(42–249)	35·2				
(Gluyas x Hope) x Ranee 4H x Ranee 4H x Ranee 4H	(43–23)	34·1	42·8	41·3†	39·0†	65·9
(Gluyas x Hope) x Ranee 4H x Ranee 4H ..	(42–88)	33·5				
Warigo		33·3	44·0	42·4†	39·1*	66·4
					39·6†	
Koorda			47·0	25·5†		65·4
Cadia x Sword	RAC (20)		46·9	37·1†		67·3
(Gluyas x Hope) x Ranee 4H x Ranee 4H x Ranee 4H	(43–26)		40·8			66·9
((Kenya Crossbred (early) x Ghurka) x (Gluyas x Hope)) x Ghurka x Ghurka ..	(43–62)			46·3*	44·7†	
Yalta				41·6*		
Celebration				39·8*		
Kondut				34·8*		
Dundee				30·3*	32·2*	
Federation				21·9*	24·9*	
Eureka II				38·7†		
Javelin				29·5†	38·8†	
Waria				26·2†		
Insignia					41·1†	
Gabo x Ridley (5)	(45S–62)				43·7*	
Kendee					43·4*	
Gabo x Dundee (3)	(716)				41·5*	
Gabo x Ridley (4)	(2663)				38·1*	
Gabo x Dundee (4)	(2640)				37·9*	
Gabo x Javelin (4)	(8784)				44·7†	
Gabo x Javelin (4)	(2701)				40·7†	
Gabo x Ranee 4H (4)	(2714)				38·1†	
Gabo x Ranee 4H (5)	(45S–60)				34·2†	
Differences between two means, significant at 5 per cent. level (bush. per ac.)		2·5	4·0	2·9*	3·3*	
				2·6†	4·5†	

C. Late sown plots. Superphosphate: 1 cwt. per acre.

		1943	1944	1945	1946	1947	
Rainfall (seeding to harvest)		11·42	10·17	15·08	13·78	19·13	
	Strain No.	Mean yield (bush. per ac.)					Bushel Weight 1945.
Kenya Crossbred (late) x Dundee ..	(41–157)	40·5					
((Florence x Nabawa) x Free Gallipoli) x Dundee	(39–16)	40·3					
Ghurka x (Pusa 4 x Ford)	(41–143)	38·8	13·7	51·5†			67·9†
Ranee 4H		38·3	17·6	44·5*			67·2*
(Dindiloa x Ford) x Ghurka	(41–149)	37·0					
(Dindiloa x Ford) x Ghurka	(41–148)	37·0					
Kenya Crossbred (early) x Dundee ..	(40–109)	36·8					
((Florence x Nabawa) x Free Gallipoli) x Dundee	(40–136)	36·1					
Ghurka x Gluyas	(41–234)	35·3					
Nabawa x Hard Federation	(39–453)	35·0	10·9	59·9†	31·0		64·9†
Nabawa x (Nabawa x Hope)	(40–254)	35·0					
Nabawa x (Riverina x Hope) ..	(39–129)	34·5					
((Gluyas x Hope) x Sepoy (Rust Resistant Selection)) x Ghurka ..	(42–96)		15·9	44·4*			64·4*
Scimitar			15·0			36·0*	
Kenya Crossbred (late) x Dundee ..	(42–246)		13·7	43·1*			64·9*
Kenya Crossbred (late) x Dundee ..	(42–247)		13·6				
Nabawa x (Nabawa x Hope)	(41–249)		13·6				
((Gluyas x Hope) x Hard Federation) x Dundee	(42–206)		12·2				
(Gluyas x Hope) x Ranee 4H x Ranee 4H x Ranee 4H	(43–28)		15·8	39·7*	46·8	39·2†	65·8*
(Gluyas x Hope) x Ranee 4H x Ranee 4H	(42–79)		15·3	57·4†	54·7	40·5†	66·4†
(Gluyas x Hope) x Ranee 4H x Ranee 4H x Ranee 4H	(43–31)		15·2	40·9*	48·9		66·3*
(Gluyas x Hope) x Ranee 4H x Ranee 4H x Ranee 4H	(43–29)		14·8				
Gabo			12·6	57·8†	47·6	39·9†	66·2†
Pusa 4				46·2*			67·5*
Waria				46·0*			66·0*
Javelin	RAC (5)			45·9*	28·8		66·9*
Ford x Dundee(5)				56·4†			67·4†
White Federation 38				44·2*	22·3	29·7†	65·2*
Gluwari				42·3*			66·5*
White Federation 38(5) x Eureka ..	(45–2581)				45·1		
Insignia					42·2		
Frisco					39·3		
Gabo x Bencubbin(4)	(2752)					38·5*	
Warigo						36·6*	
Gabo x Bencubbin(4)	(2756)					36·5*	
Gabo x Scimitar(4)	(2820)					36·2*	
Gabo x Bencubbin(5)	(8933)					33·4*	
Bencubbin						31·9*	
Gabo x Rapier(3)	(2794)					31·0*	
Gabo x Rapier(4)	(2786)					29·0*	
Rapier						28·8*	
Gabo x Dirk(3)	(726)					47·2†	
Gabo x Dirk(4)	(2842)					40·9†	
Dirk						40·3†	
Gabo x Dirk(3)	(724)					40·1†	
Kenya Crossbred x Federation(4) ..	(2780)					39·9†	
White Federation 45						38·8†	
Differences between two means, significant at 5 per cent. level of probability (bush. per ac.)		4·6	1·7	2·6* 5·1†	3·8	4·6* 4·4†	

5A. MID-SEASON SOWN SMALL FIELD PLOTS AT WAITE INSTITUTE, 1947.

Date of sowing: 23rd June.
Seed rate: 80 lb. per ac.
Superphosphate: 1 cwt. per ac.
Area of plot: 1/84th ac.
Rainfall (seeding to harvest): 19·40 in.
Design: Randomized blocks of 4 replications.

I. *Back-cross Seewari and Ghurka and Their Parent Types.*

	Strain No.	Mean yield. Bush. per ac.
1. Ghurka		35·0
2. Gabo x Ghurka(4)	(2705)	29·8
3. Gabo x Seewari(5)	(45S–64)	28·0
4. Seewari		21·9

Differences between 2 means of 1·2 bush. per ac. are significant at 5 per cent. level of probability.

II. *Back-cross Ridley and Dundee and Their Parent Types.*

	Strain No.	Mean yield. Bush. per ac.
1. Gabo x Ridley(5)	(45S–62)	40·2
2. Gabo x Dundee(4)	(2640)	34·4
3. Ridley		30·2
4. Dundee		25·4

Differences between 2 means of 2·7 bush. per ac. are significant at 5 per cent. level of probability.

III. *Back-cross Javelin and Ranee 4H and Their Parent Types.*

	Strain No.	Mean yield. Bush. per ac.
1. Gabo x Javelin(4)	(8784)	30·6
2. Javelin		26·2
3. Gabo x Ranee 4H(5)	(45S–60)	21·2
4. Ranee 4H		13·4

Differences between 2 means of 1·0 bush per ac. are significant at 5 per cent. level of probability.

IV. *Back-cross Dirk and Scimitar and Their Parent Types.*

	Strain No.	Mean yield. Bush. per ac.
1. Gabo x Dirk(4)	(2842)	45·4
2. Dirk		42·7
3. Gabo x Scimitar(4)	(2820)	33·1
4. Scimitar		32·4

Differences between 2 means of 3·2 bush. per ac. are significant at 5 per cent. level of probability.

V. *Nabawa* x (*Riverina* x *Hope*) *Selections.*

	Strain No.	Mean yield. Bush. per ac.
1. Warigo		45·7
2. Nabawa x (Riverina x Hope)	(39–129)	41·8
3. Nabawa x (Riverina x Hope)	(38–356)	40·6
4. Ranee 4H		18·7

Differences between 2 means of 2·6 bush. per ac. are significant at 5 per cent. level of probability.

N.B. At the Waite Institute a significant, but not intense, infection of rust occurred evenly throughout the plots. The mid-season sown plots were affected to a greater extent than the early sown and late sown plots.

6. YIELD TRIALS OF CROSSBRED WHEATS AND VARIETIES AT SADDLEWORTH. 1943–47.

		1943.	1944.	1945.	1946.	1947.
Superphosphate in lb. per ac.		120	120	120	180	190
Rainfall (seeding to harvest)		10·33	7·01	11·80	10·20	14·15
YIELD.	**Strain No.**	**Mean yield (bush. per ac.)**				
Tuela Ghurka		50·81	8·3	29·42	27·01	54·7
		39·72				
Nabawa x (Riverina x Hope)	(38–356)	50·81	8·4	29·81	48·82	
Eureka II		48·71	10·0	28·01	44·42	
Warigo		45·81	11·5	29·31	55·42	54·7
Kenya Crossbred (early) x Dundee	(40–109)	45·11	10·8	32·01	48·22	48·3
(Gluyas x Hope) x Ghurka	(41–14)	41·91				
Bobin x Gaza x Bobin	(24–1–1)	40·81				
(Gluyas x Hope) x Nabawa	(39–248)	40·41				
Quadrat		40·72	9·8	31·42	29·91	25·4
Ford x Dundee(5)	RAC (5)	39·92	12·4	34·91	23·12	
Seewari		37·12				
((Florence x Nabawa) x Free Gallipoli) x Dundee	(40–136)	31·22				
Ridley	(37–443)	29·02				
Ranee 4H		28·72				
Ghurka x (Zealand Blue x Wannon)		24·72				
Nabawa x (Riverina x Hope)	(39–129)		11·6	25·21	47·72	
(Gluyas x Hope) x Ghurka x Ghurka x Ghurka	(43–46)			27·32	37·71	40·2
Kenya Crossbred (early) x Ghurka	(41–142)			26·92	41·21	41·6
(Gluyas x Hope) x Ghurka x Ghurka x Ghurka	(43–38)			26·22		
(Gluyas x Hope) x Ghurka x Ghurka x Ghurka	(43–47)			25·32		
Insignia					31·81	23·2
Pinnacle					20·91	20·6
Gabo x (Ford x Dundee(5))4	(2841)					58·3
Kendee						53·0
((Kenya Crossbred (early) x Ghurka) x (Gluyas x Hope)) x Ghurka x Ghurka	(43–62)					43·3
Ford x Dundee(5)						23·1
Differences between two means, significant at 5 per cent. (bush per ac.)		8·61	0·6	3·31	1·91	3·5
		4·42		1·72	2·32	

BUSHEL WEIGHT.	**Strain No.**	**1943.**	**1944.**	**1945.**	**1946.**	**1947.**
Tuela Ghurka		66·3	61·0	59·3	53·6	
		66·3				
Nabawa x (Riverina x Hope)	(38–356)	65·0	58·5	58·5	59·2	
Eureka II		65·0	60·3	60·1	62·1	
Warigo		65·0	56·3	59·6	60·8	64·0
Kenya Crossbred (early) x Dundee	(40–109)	65·8	57·8	58·8	60·1	64·0
(Gluyas x Hope) x Ghurka	(41–14)	63·8				
Bobin x Gaza x Bobin	(24–1–1)	63·8				
(Gluyas x Hope) x Nabawa	(39–248)	63·5				
Quadrat		65·0	59·8	60·2	52·1	52·0
Ford x Dundee(5)	RAC (5)	65·3	58·5	60·5	55·6	
Seewari		64·5				
((Florence x Nabawa) x Free Gallipoli) x Dundee	(40–136)	65·8				
Ridley	(37–443)	64·5				
Ranee 4H		66·0				
Ghurka x (Zealand Blue x Wannon)		—				
Nabawa x (Riverina x Hope)	(39–129)		56·5	57·6	59·1	
(Gluyas x Hope) x Ghurka x Ghurka x Ghurka	(43–46)			59·3	58·8	60·5

	Strain No.	1943.	1944.	1945.	1946.	1947.
Kenya Crossbred (early) x Ghurka	(41–142)			61·2	62·3	64·5
(Gluyas x Hope) x Ghurka x Ghurka x Ghurka	(43–38)			60·4		
(Gluyas x Hope) x Ghurka x Ghurka x Ghurka	(43–47)			60·4		
Insignia					56·9	55·0
Pinnacle					48·1	47·8
Gabo x (Ford x Dundee(5))4	(2841)					64·8
Kendee						61·8
((Kenya Crossbred (early) x Ghurka) x Gluyas x Hope) x Ghurka x Ghurka ..	(43–62)					61·8
Ford x Dundee(5)						52·0

7. YIELD TRIALS OF CROSSBRED WHEATS AND VARIETIES AT PALLAMANA, 1944–47.

		1944.	1945.	1946.	1947.
Superphosphate in lbs. per ac.		120	90	90	112
Rainfall (seeding to harvest)		4·31	8·89	7·66	9·92
	Strain No.	Mean yield (bush. per ac.)			
Nabawa x (Riverina x Hope)	(39–129)	12·8	9·7	26·0	38·1
Bencubbin		11·6	10·3	17·2	28·4
Warigo		11·1	8·2	29·1	35·1
Gabo		10·7	10·1	31·7	39·1
Koorda		10·6	9·2	13·2	
Ranee 4H		10·4	9·1	9·4	20·6
Nabawa x Hard Federation	(39–453)	10·3	8·3	16·2	
Ridley		9·8	6·7		
Javelin		9·7	9·1	13·9	26·2
Scimitar		9·3	7·3		
Kenya Crossbred (early) x Dundee	(40–109)	9·2			
Ford x Dundee(5)		7·7	8·8	18·6	
(Gluyas x Hope) x Ranee 4H x Ranee 4H x Ranee 4H	(43–28)		10·5	30·1	36·1
Insignia				24·2	33·8
Bungulla				23·5	29·0
(Gluyas x Hope) x Ranee 4H x Ranee 4H	(42–79)				38·8
Gabo x Javelin(4)	(2701)				35·4
Gabo x Ranee 4H(5)	(8906)				30·4
Differences between means, significant at 5 per cent. level (bush. per ac.)		1·0	1·6	2·8	4·92
BUSHEL WEIGHT.					
Nabawa x (Riverina x Hope)	(39–129)	63·8		62·3	63·3
Bencubbin		63·8		59·0	62·5
Warigo		64·0		63·5	63·5
Gabo		63·8		60·8	62·5
Koorda		63·3		57·0	
Ranee 4H		65·3		59·5	64·5
Nabawa x Hard Federation	(39–453)	62·8		57·0	
Ridley		63·5			
Javelin		64·3		58·8	63·0
Scimitar		66·5			
Kenya Crossbred (early) x Dundee	(40–109)	63·5			
Ford x Dundee(5)		63·8		63·0	65·3
(Gluyas x Hope) x Ranee 4H x Ranee 4H x Ranee 4H	(43–28)			64·0	65·0
Insignia				59·8	62·0
Bungulla	RAC (5)			60·0	
(Gluyas x Hope) x Ranee 4H x Ranee 4H	(42–79)				64·5
Gabo x Javelin(4)	(2701)				64·5
Gabo x Ranee 4H(5)	(8906)				65·0

8. YIELD TRIALS OF BARLEY VARIETIES, 1943–44.

Superphosphate: 1 cwt. per ac.

		1943.	1944.
Rainfall (seeding to harvest)		13·050	10·090
	Strain No.	Mean yield (bush. per ac.).	
Cape-Waite Institute Selection (1) ..		74·2	25·8
Cape x Smooth Awn	(39–709)	67·4	18·9
Flynn		65·2	25·8
Maltworthy		62·4	26·6
Research		57·5	24·9
Prior		52·7	25·5
Trabut			28·7
Atlas			24·6
Cape-Waite Institute Selection (2) ..			23·9
Cape-Werribee, Victoria			23·6
Roseworthy Oregon			22·9
Differences between 2 means significant at 5 per cent. probability level (bush. per ac.)		—	5·06

9. YIELD TRIALS OF PEA VARIETIES (1943–47).

1943.

Superphosphate: 1 cwt. per ac.
Rainfall (seeding to harvest): 13·60 in. Date of sowing: 1st June.

	Varieties.						
	Dutch Blue.	Collegian.	White Brunswick.	Dun.	Tasmanian Blue.	Green-feast.	Mammoth Blue.
Seed rate (lb. per ac.)	120	120	120	120	120	120	120
Seedlings per foot	2·4	2·9	3·4	2·6	1·5	1·1	1·7
Date of flowering	8/9/43	2/9/43	2/9/43	20/9/43	20/9/43	8/9/43	20/9/43
Mean yield (bush. per ac.)	**52·6**	**42·4**	**41·8**	**32·5**	**27·8**	**25·7**	**24·2**

Differences between two means of 4·2 bush. per ac. are significant at 5 per cent. level of probability.

1944.

Rainfall (seeding to harvest): 10·12 in. Date of sowing: 18th May.

	Dutch Blue.	Collegian.	White Brunswick.	Dun.	Tasmanian Blue.	Green-feast.	Mammoth Blue.
Seed rate (lb. per ac.)	120	120	120	120		120	
Seedlings per foot	3·3	3·7	3·5	4·2		2·7	
Date of flowering	24/8/44	15/8/44	15/8/44	4/9/44		24/8/44	
Mean yield (bush. per ac.)	**16·6***	**24·0**	**43·3**	**21·9**		**14·8***	

Differences between two means of 1·8 bush. per ac. are significant at 5 per cent. level of probability.

* Additional loss of seed in harvesting (estimated): Dutch Blue 5·5 bush. per ac.
Greenfeast 4·2 bush. per ac.

1945.

Rainfall (seeding to harvest): 14·5 in. Date of sowing: 23rd May.

	Dutch Blue.	White Collegian.	White Brunswick.	White Dun.	Tasmanian Blue.	Green-feast.	Mammoth Blue.
Seed rate (lb. per ac.)	161	120	115	103		156	
Seedlings per foot	2·7	3·7	3·6	3·0		3·3	
Date of flowering	31/8/45	13/8/45	13/8/45	13/9/45		29/8/45	
Mean yield (bush. per ac.)	**28·3**	**24·3**	**22·8**	**20·3**		**30·6**	

Differences between two means of 4·6 bush. per ac. are significant at 5 per cent. level of probability.

1946.

Rainfall (seeding to harvest): 14·56 in. Date of sowing: 23rd May.

	Dutch Blue.	White Collegian.	White Brunswick.	White Dun.	Tasmanian Blue.	Green-feast.	Mammoth Blue.
Seed rate (lb. per ac.)	194	120	115	103		156	
Seedlings per foot	3·5	2·7	3·0	3·2		3·2	
Date of flowering	24/8/46	9/8/46	9/8/46	6/9/46		26/8/46	
Mean yield (bush. per ac.)	**36·3**	**33·9**	**34·1**	**39·9**		**16·1**	

Differences between two means of 2·6 bush. per ac. are significant at 5 per cent. level of probability.

1947.

Rainfall (seeding to harvest): 12·53 in. Date of sowing: 27th May.

	Dutch Blue.	White Collegian.	White Brunswick.	White Dun.	Tasmanian Blue.	Green-feast.	Mammoth Blue.
Seed rate (lb. per ac.)	155	120	109	103		156	
Seedlings per foot	2·8	2·2	2·5	2·6		2·9	
Date of flowering	2/9/47	18/8/47	17/8/47	16/9/47		28/8/47	
Mean yield (bush. per ac.)	**38·0**	**36·3**	**43·7**	**37·5**		**41·6**	

Differences between two means of 4·6 bush. per ac. are significant at 5 per cent. level of probability.

Supplementary Trials.

1945.

Rainfall (seeding to harvest): 14·5 in. Date of Sowing: 23rd May.

	Massey.	Thomas Laxton.	Wilt Resistant Surprise.
Seed rate (lb. per ac.)	216	205	188
Seedlings per foot	3·0	3·2	4·3
Date of flowering	28/7/45	24/7/45	24/7/45
Mean yield (bush. per ac.)	**16·2**	**14·7**	**12·2**

Differences between two means of 2·4 bush. per ac. are significant at 5 per cent. level of probability.

1947.

Rainfall (seeding to harvest): 12·53 in. Date of sowing: 26th June.

	White Brunswick.	Alaska.
Seed rate (lb. per ac.)	109	109
Seedlings per foot	2·4	2·5
Date of flowering	18/9/47	31/8/47
Mean yield (bush. per ac.)	**53·3**	**32·3**

Differences between two means of 4·7 bush. per ac. are significant at 5 per cent. level of probability.

10. FLAX VARIETY TRIALS, 1943–46.

1943.

Date of sowing: 2nd June.
Seed rate: 70 lb. per ac.
Superphosphate: 104 lb. per ac.
Area of plot: 1/61st ac.
Rainfall (seeding to harvest): 13·40 in.
Design: Randomized blocks of 4 replications.

	Liral Crown.	Concurrent.	Liral Prince.	Giza Purple.
Seedlings per sq. foot	84·5	76·0	59·0	44·5
Height (ft.)	2·7	2·7	2·8	2·5
Bolls per plant	4·6	4·3	4·9	9·1
Seeds per boll	8·8	9·1	8·2	9·0
Date of flowering	22/9/43	2/10/43	23/9/43	2/10/43
Mean weight of Handpulled straw				
(a) Undeseeded cwt. per ac.	61·4	53·1	49·3	41·5
(b) Deseeded cwt. per ac.	49·6	39·6	39·4	29·3
Mean yield of seed, bush. per ac.	**12·9**	**16·1**	**11·4**	**14·3**

1944.

Date of sowing: 17th May.
Seed rate: 70 lb. per ac.
Superphosphate: 1 cwt. per ac.
Area of plot: 1/56th ac.
Rainfall (seeding to harvest): 10·12 in.
Design: Randomized blocks of 4 replications.

	Liral Crown.	Concurrent.	Liral Prince.	Giza Purple.	Liral Monarch.	Concurrent (Canberra).	Stormont Gossamer.
Seedlings per foot	68	69	74	71	79	70	59
Height (ft.)	2·8	2·4	2·8	2·2	2·6	2·3	2·8
Bolls per plant	2·1	2·2	1·9	2·1	2·3	2·8	2·9
Seeds per boll	7·9	8·6	7·6	8·1	8·0	9·0	7·6
Date of flowering	8/9/44	17/9/44	8/9/44	20/9/44	7/9/44	17/9/44	5/9/44
Weight of 1,000 seeds (gm.)	4·4	4·2	3·9	4·3	3·9	4·5	3·9
Grub damage, per cent.	9	17	16	22	14	32	23
Mean weight of Handpulled straw							
(a) Undeseeded cwt. per ac.	34·6	32·7	36·6	37·8	36·6	33·8	31·6
(b) Deseeded cwt. per ac.	28·1	23·9	30·6	28·2	29·7	25·8	26·2
Mean yield of seed, bush. per ac.	**5·0**	**7·4**	**3·5**	**8·2**	**5·2**	**6·9**	**3·9**

Drought conditions prevailed during the latter part of the growing period.
Cutworm infestation fairly severe in September: subsequently controlled by 2 dustings with Lead Arsenate.

1945.

Date of sowing: 17th May.
Seed rate: 78 lb. per ac.
Superphosphate: 1 cwt. per ac.
Area of plot: 1/42nd ac.
Rainfall (seeding to harvest): 14·6 in.
Design: Randomized blocks of 4 replications.

	Liral Crown.	Concurrent.	Liral Prince.	Giza Purple.	Liral Monarch.	Concurrent (Canberra).	Stormont Gossamer.
Seedlings per foot	61	66	61	68	63	62	54
Height (ft.)	2·6	2·7	2·7	2·5	2·6	2·7	2·7
Bolls per plant	6·2	5·8	4·6	6·1	5·4	5·6	7·0
Seeds per boll	9·4	7·9	8·6	8·5	9·0	7·7	9·2
Date of flowering	5/9/45	12/9/45	5/9/45	16/9/45	5/9/45	12/9/45	4/9/45
Weight of 1,000 seeds (gm.)	4·3	4·3	4·0	4·4	4·0	4·2	4·0
Mean weight of Handpulled straw							
(a) Undeseeded cwt per ac.	46·4	43·7	45·2	39·4	50·6	39·8	36·8
(b) Deseeded cwt. per ac.	31·1	29·0	30·1	24·4	33·1	25·4	24·4
Mean yield of seed (bush. per ac.)	**9·1**	**10·1**	**8·3**	**11·8**	**8·3**	**9·3**	**7·3**

Soursobs very bad during June.
Heavy rains in September caused lodging, but there was no resultant loss of straw.

1946.

Date of sowing: 24th May.
Seed rate: 76 lb. per ac.
Superphosphate: 1 cwt. per ac.

Area of plot: 1/45th ac.
Rainfall (seeding to harvest): 13·85 in.
Design: Randomized blocks of 4 replications.

	Liral Crown.	Concurrent.	Liral Prince.	Giza Purple.	Liral Monarch.	Wada.	Norfolk Earl.
Seedlings per foot	59	68	62	67	65	123	63
Height (ft.)	2·7	2·9	3·0	2·7	2·9	2·9	2·7
Bolls per plant	4·2	2·7	4·0	4·3	4·8	2·9	4·3
Seeds per boll	7·9	8·0	8·2	7·8	8·5	8·1	7·7
Date of flowering	14/9/46	26/9/46	14/9/46	26/9/46	14/9/46	14/9/46	13/9/46
Weight of 1,000 seeds (gm.)	4·3	4·6	4·3	4·7	4·1	4·1	4·5
Mean weight of Handpulled straw							
(a) Undeseeded cwt. per ac.	56·3	55·6	52·9	50·2	55·8	55·9	48·5
(b) Deseeded cwt. per ac.	43·3	42·4	43·5	37·1	43·3	46·2	38·7
Mean yield of seed (bush. per ac.)	13·0	13·3	11·0	14·0	12·9	9·3	10·7

General seasonal conditions favourable for flax.

11. SAFFLOWER VARIETY TRIALS, 1944–47.

1944.

Date of sowing: 8th June.
Seed rate: 55 lb. per ac.
Superphosphate: 1 cwt. per ac.

Area of plot: 1/74th ac.
Rainfall (seeding to harvest): 11·86 in.
Design: Single plots.

	Niphad 630.	Niphad Local.	U.S.A. Strain.	Western Australian Strain.
Bushel weight (lb)	47	47	50	45·5
Weight of 1,000 seeds (gm.)	65	57	37	34
Yield lb. per ac.	852	704	585	370
Oil content, per cent.	27·1	—	23·9	—
Ether extracted oil				
Acid value	1·2	—	1·1	—
Iodine value (Wijs)	145·8	—	149·0	—

The method of harvesting was not satisfactory and approximately 50 lb. of seed per ac. was lost during the process.

Oil values determined by Messrs. Meggits Limited.

1945.

Date of sowing: 24th May.
Seed rate: 57 lb. per ac.
Superphosphate: 1 cwt. per ac.

Area of plot: 1/20th ac.
Rainfall (seeding to harvest): 18·49 in.
Design: Randomized blocks of 4 replications.

	Niphad 630.	Niphad Local.	U.S.A. Strain.
Seedlings per foot	2·5	2·2	2·3
Date of flowering	20/11/45	20/11/45	1/12/45
Bushel weight (lb.)	49·3	49·3	47·1
Weight of 1,000 seeds (gm.)	54	48	34
Mean yield (lb. per ac.)	1,586	1,334	854
Oil content, per cent.	24·3	25·0	22·0
Iodine value (Wijs)	144·4	145·8	146·0

Differences between 2 mean yields of 27·6 lb. per ac. are significant at 5 per cent. level of probability.

Oil values determined by The Commonwealth Munitions Supply Laboratories.

1946.

Date of sowing: 24th May.
Seed rate: 60 lb. per ac.
Superphosphate: 1 cwt. per ac.

Area of plot: 1/27th ac.; except plots 3, 4, 5 and 7: 1/60th ac.
Rainfall (seeding to harvest): 18·88 in.
Design: single plots.

	Niphad 630.	Niphad Local.	U.S.A. Strain.	Pusa 7./	Karrar.	Russian.	Pusa 2.	N.9.	N.7.	Niphad 630 (sown alternate hoes).
Seedlings per foot	3·2	3·2	3·4	4·2	3·6	2·6	3·6	1·0	0·8	1·6
Bushel weight (lb.)	48·2	48·6	46·0	48·2	47·2	44·0	48·3	46·7	46·3	—
Weight of 1,000 seeds (gm.)	42	44	31	41	41 /	36	37	56	59	—
Yield (lb. per ac.)	1,684	1,304	1,042	1,432*	1,414	1,315	1,069*	1,075	859	1,119
Composition of seed										
1. Hull	59·3	57·5	61·4	60·4	60·1	57·8	58·3	56·5	55·9	—
2. Meats	40·7	42·5	38·6	39·6	39·9	42·2	41·7	43·5	44·1	—
3. Moisture	8·6	6·6	7·4	7·9	7·6	8·2	7·1	6·8	7·4	—
4. Oil	22·1	24·9	22·1	23·2	23·0	24·1	24·5	24·8	24·3	—
Iodine value (Wijs)	147·5	146·0	147·5	147·5	147·0	149·0	147·0	145·0	144·0	—

Composition of seed and iodine values determined by the Commonwealth Munitions Supply Laboratories.
N.7 and N.9 are large seeded varieties so that seedlings per foot are lower.
* An additional 50 lb. per ac. (approx.) lost while harvesting due to shattering.

1947.

Date of sowing: 28th May.
Seed rate: 48 lb. per ac.; N.7 and N.9 60 lb. per ac.
Superphosphate: 1 cwt. per ac.

Area of plot: 1/47th ac.
Rainfall (seeding to harvest): 20·56 in.
Design: Randomized blocks of 3 replications.

	Niphad 630.	U.S.A. Strain.	Russian.	N.7.	Pusa 2.	Pusa 7.	Karrar.	N.9.
Seedlings per foot	1·3	1·2	2·2	0·8	1·2	1·2	1·4	1·1
Bushel weight (lb.)	50·0	49·0	48·0	49·8	49·8	50·0	48·5	49·5
Weight of 1,000 seeds (gm.)	43·5	33·6	41·0	59·5	41·0	43·7	41·4	58·4
Mean yield (lb. per ac.)	803	404	1,403	734	729	716	703	659

TIME AND RATE OF SOWING TRIAL.

1946.

Variety: Niphad 630.
Superphosphate: 1 cwt. per ac.

Area of plot: 1/27th ac.
Rainfall (seeding to harvest): Sown 24th May, 18·88 in.; sown 22nd June, 15·72 in.
Design: Randomized blocks of 3 replications.

Plots.	Date of sowing.	Seed rate (lb. per ac.)	Seedlings per ft.	Height (ft.)	Bushel Weight (lb.)	Weight of 1,000 seeds (gm.)	Mean yield (lb. per ac.)
1	24/5/46	60	3·3	4–4·5	48·2	45·6	1,566
2	24/5/46	40	3·0	4–4·5	48·2	45·6	1,495
3	22/6/46	60	1·1	3·5	46·3	44·0	439
4	22/6/46	40	1·2	3·5	46·3	44·0	428

Differences between 2 mean yields of 118 lb. per ac. are significant at 5 per cent. level of probability.

The marked apparent difference in yield due to time of sowing was caused predominantly by the soil sealing effect brought about by heavy rains that fell just after late sowings.

1947.

Variety: Niphad 630.
Superphosphate: 1 cwt. per ac.

Area of plot: 1/47th ac.
Rainfall (seeding to harvest): Sown 28th May, 20·56 in.; sown 17th June, 19·68 in.
Design: Randomized blocks of 2 replications.

Plots.	Date of sowing.	Seed rate (lb. per ac.).	Seedlings per foot.	Mean yield (lb. per ac.).
1	17/6/47	60	3·3	1,024
2	17/6/47	30	2·0	966
3	28/5/47	60	2·0	881
4	28/5/47	30	1·4	594

Differences between 2 mean yields of 204 lb. per ac. are significant at 5 p.c. level of probability.

Three replicates sown, but first replicate deleted due to the invasion of wild oats.

12. INFLUENCE OF TOP DRESSING ON THE YIELD AND CARRYING CAPACITY OF NATURAL PASTURE, 1925–47.

Investigation commenced in 1925 on unimproved natural grassland dominated by *Danthonia* spp.

Manurial treatments:

(a) Natural pasture.

A. Superphosphate: 185 lb. (40 lb. P_2O_5) per ac.
B. Superphosphate: 185 lb. + nitrate of soda, 78 lb. (12½ lb. N) per ac.
C. Nil.
D. Ground rock phosphate, 103 lb. (40 lb. P_2O_5) per ac.
E. Basic Slag, 260 lb. (40 lb. P_2O_5) per ac.
} annually from 1925.

F. Superphosphate: 92·5 lb. (20 lb. P_2O_5) per ac.

(b) Seeded pasture.

G. Superphosphate: 185 lb. (40 lb. P_2O_5) per ac.
H. Superphosphate: 185 lb. (40 lb. P_2O_5) per ac.
} annually from 1940.

Design: Single replication of each treatment.

Area of plot: $\frac{13}{15}$th ac. subdivided into 5 equal areas. Ten quadrat areas each of 2½ square metres are protected from grazing and are cut for determination of yield at end of season.

Each section of the whole plot is grazed in rotation by a flock of Merino wethers assigned to it; their grazing is restricted to the particular plot or pasture similarly treated.

The pasture of plot F consists mainly of annual species while plots G and H consist of a seeded pasture, of which *Phalaris tuberosa* is the main species. Hay is cut from one section of plot H in each year and fed back to the sheep during the winter.

Total yield in cwt. air-dry herbage per acre.

	Treatment.									
Year.	A	B	C	D	E	F	G	H	Mean A–E	Mean A–H
1925	27·74	30·69	21·76	18·57	25·49				**24·85**	
1926	43·20	43·57	28·35	27·16	49·15				**38·29**	
1927	28·54	27·95	18·00	15·95	24·84				**23·06**	
1928	39·63	41·81	24·31	27·89	35·58				**33·84**	
1929	33·70	37·45	17·69	25·63	35·31				**29·96**	
1930	30·32	39·86	20·67	30·56	43·56				**32·99**	
1931	47·50	63·12	41·43	52·60	58·06				**52·54**	
1932	75·66	81·11	56·92	70·34	78·25				**72·46**	
1933	64·70	63·58	51·43	61·72	57·61				**59·81**	
1934	38·00	52·44	20·23	43·66	48·67				**40·60**	
1935	72·90	70·90	41·49	58·25	62·72				**61·25**	
1936	42·24	48·67	29·54	47·30	41·15				**41·78**	
1937	51·69	59·09	36·21	59·48	61·07				**53·51**	
1938	54·47	57·62	34·92	60·11	64·06				**54·24**	
1939	50·57	66·37	48·97	63·36	62·40				**58·33**	
1940	26·48	30·30	29·48	33·86	28·41	42·30	49·10	51·00		**36·37**
1941	37·04	42·83	35·64	46·32	43·77	54·65	59·30	60·57		**47·52**
1942	54·74	70·14	45·17	66·08	65·26	70·41	80·82	82·84		**66·93**
1943	63·43	65·60	56·34	58·66	81·30	68·12	85·59	89·51		**71·07**
1944	44·43	47·80	35·95	54·59	51·54	48·96	48·02	54·29		**48·20**
1945	50·88	54·48	39·67	59·42	60·80	56·74	67·95	64·19		**56·77**
1946	66·24	60·46	56·18	71·32	69·96	65·68	77·34	81·90		**68·64**
1947	62·88	64·22	45·48	63·62	72·90	64·63	61·93	68·25		**62·99**
Mean 1925–47	**48·13**	**53·05**	**36·34**	**48·54**	**53·12**					
Mean 1940–47						**58·94**	**66·26**	**69·07**		

Yield of Legumes in the pasture, cwt. air-dry herbage per ac.

	Treatment.									
Year.	A	B	C	D	E	F	G	H	Mean A–E	Mean A–H
1925	20·25	18·35	6·57	5·64	14·35				13·03	
1926	20·17	16·66	9·49	9·18	19·12				14·92	
1927	4·29	0·40	1·02	0·44	2·43				1·72	
1928	23·00	13·78	0·90	3·81	4·28				9·15	
1929	14·45	8·24	2·18	4·74	13·30				8·58	
1930	1·71	0·54	0·39	1·57	1·63				1·17	
1931	6·80	2·79	3·56	5·33	5·18				4·73	
1932	9·35	7·33	9·94	18·01	12·58				11·44	
1933	5·40	2·23	4·20	4·24	3·10				3·83	
1934	1·89	1·17	2·34	1·95	0·06				1·48	
1935	44·53	27·97	10·14	20·69	18·63				24·39	
1936	7·84	14·89	8·82	15·08	9·95				11·32	
1937	19·30	15·15	9·69	14·63	31·34				18·02	
1938	14·31	4·40	6·83	17·50	15·85				11·78	
1939	6·85	4·13	12·73	17·73	11·26				10·54	
1940	5·48	4·43	3·16	1·83	3·37	4·78	13·94	15·67		6·58
1941	9·73	3·62	2·54	1·45	2·06	Nil	12·78	15·07		5·91
1942	2·58	3·40	3·37	1·45	3·00	1·61	1·63	2·06		2·39
1943	7·80	11·05	6·04	5·82	14·27	9·97	36·63	35·69		15·91
1944	1·37	0·55	3·52	7·24	1·65	0·13	0·24	1·05		1·97
1945	16·98	17·69	4·95	2·18	8·79	6·70	7·62	20·73		10·71
1946	14·12	4·44	10·11	15·53	8·48	3·79	7·78	7·73		9·00
1947	29·98	22·25	13·98	26·58	25·35	15·11	11·05	23·20		20·94
Mean 1925–47	12·53	8·93	5·93	8·81	10·00					
Mean 1940–47						5·26	11·46	15·15		

Stock-carrying capacity. Sheep days of grazing per ac.

	Treatment.								
Year.	A	B	C	D	E	F	G	H	Mean.
Mean 1928-42	1,512	1,704	1,030	1,452	1,630				
Mean 1940–42						1,510	1,537	1,581	
1943	1,821	1,706	1,475	1,832	1,800	1,745	1,875	1,865	1,765
1944	1,385	1,392	885	1,355	1,210	1,364	1,273	1,321	1,273
1945	1,670	1,723	1,355	1,733	1,683	1,836	1,847	1,776	1,703
1946	1,868	1,855	1,321	1,812	1,788	1,959	2,023	1,620	1,781
1947	2,040	1,978	1,434	2,042	2,121	2,015	2,446	2,410	2,061
Mean 1928–47	1,574	1,711	1,096	1,528	1,643				
Mean 1940–47						1,681	1,759	1,717	

13. EFFECT OF SUPERPHOSPHATE AND SURFACE CULTIVATION ON THE YIELD OF A SEEDED PASTURE, 1937–47.

Pasture mixture: *Phalaris tuberosa*, Wimmera rye-grass, Dwalganup subterranean clover. Sown 15th May, 1936.

Superphosphate: Dressing applied per ac. per annum, P_0 = nil, P_1 = 1 cwt., P_2 = 2 cwt., P_3 = 3 cwt.

Cultivation: C_0 = nil, C_1 = surface cultivated each autumn up to and including 1944.

Design: Phosphate treatments arranged in a 4 × 4 Latin Square.

Area of main plot: $\frac{1}{12.5}$th ac. Half of each plot surface cultivated. Plots sampled for yield and grazed 4 times annually at approximately 6-weekly intervals.

Yield of oven-dry herbage in cwt. per ac.

	P_0	P_1	P_2	P_3	
Mean 1937–42	35·17	41·46	42·64	43·00	
		Means ± 1.255			Mean ± 0·628
1943	57·75	66·00	66·57	64·06	**63·60**
1944	41·27	44·05	45·44	49·96	**45·18**
1945	44·16	47·03	49·84	49·89	**47·73**
1946	57·82	56·31	62·27	54·15	**57·64**
1947	45·60	49·59	50·41	48·29	**48·47**
Mean 1937–47 ± 0·797	41·60	46·52	48·22	47·67	

14. INFLUENCE OF VARYING PASTURE MANAGEMENT OF SEEDED PASTURE AT KYBYBOLITE AND WAITE INSTITUTE ON LIVE WEIGHT AND WOOL PRODUCTION OF MERINO AND ROMNEY MARSH-MERINO WETHERS.

Pasture mixture: *Phalaris tuberosa*, Wimmera rye-grass and subterranean clover sown on 17th April, 1939 at Kybybolite, and on 2nd May at the Waite Institute.

Superphosphate: 2 cwt. per ac. per annum.

Treatments: 1. Continuous grazing without cutting for hay.
2. Continuous grazing and cutting for hay fed back.
3. Rotational grazing, 8-weekly in winter, fortnightly in spring during closure for hay in the 2nd and 4th treatments, 4-weekly in spring and autumn without cutting for hay.
4. Rotational grazing as above, and cutting for hay fed back.

Design: Treatments 4 (2 × 2 as above), replications 4, arrangement orthogonal.

No. of plots: 16.

Size of plots: 7 × 1·87 chains = $1\frac{5}{16}$th ac.

Plots grazed individually by a mixed flock of 10 Merinos and 10 crossbreds per grazing treatment.

Stocking rate: Arranged prior to commencement of experiment at approximately 4 sheep per ac. per annum.

Period of experiment: 1940–45.

Mean live weight increase in lb. per sheep.

CO = continuous grazing without hay.
CH = continuous grazing with hay cut and fed back.
RO = rotational grazing without hay.
RH = rotational grazing with hay cut and fed back.

Kybybolite. (9/5/40–10/1/46)—3·31 wethers per ac.

	Merino.				Romney Marsh-Merino.			
	CO	CH	RO	RH	CO	CH	RO	RH
9/5/40–18/11/43	78·5	71·4	74·3	68·8	99·2	88·9	104·5	106·3
18/11/43–10/1/46	60·7	69·0	54·4	62·3	71·6	72·4	72·0	71·4
Total	**139·2**	**140·4**	**128·7**	**131·1**	**170·8**	**161·3**	**176·5**	**177·7**

Waite Institute (9/5/40–3/6/46)—3·50 wethers per ac.

	Merino.				Romney Marsh-Merino.			
	CO	CH	RO	RH	CO	CH	RO	RH
9/5/40–18/11/43	99·9	99·2	106·5	93·1	135·2	131·4	134·3	122·8
18/11/43–3/6/46	69·5	60·7	69·5	58·0	80·9	74·9	80·0	63·7
Total	**169·4**	**159·9**	**176·0**	**151·1**	**216·1**	**206·3**	**214·3**	**186·5**

The mean weight of wool per sheep (1940–45), and the mean value of the wool (1942–45).

Kybybolite.

Merino.

	Mean weight of wool (in lb. and oz.).				Value (shillings and pence).			
	CO	CH	RO	RH	CO	CH	RO	RH
1940	10–15	11–10	10–9	10–14				
1941	13–1	14–0	12–14	13–13				
1942	11–0	11–11	10–6	10–14	12/9	13/6	11/9	12/8
1943	15–3	15–7	14–3	14–9	19/7	19/–	17/11	18/7
1944	8–7	9–1	8–7	8–0	11/4	11/7	10/10	10/5
1945	11–3	12–10	11–7	11–10	15/8	16/8	15/2	16/4
Total	69–13	74–7	67–14	69–12	59/4	60/9	55/8	58/–
Mean	**11–10**	**12–7**	**11–5**	**11–10**	**14/10**	**15/2**	**13/11**	**14/6**

Romney Marsh-Merino.

	Mean weight of wool (in lb. and oz.).				Value (shillings and pence).			
	CO	CH	RO	RH	CO	CH	RO	RH
1940	8–5	7–12	7–10	7–5				
1941	11–15	12–6	12–6	11–13				
1942	9–6	9–6	8–12	9–2	11/5	11/5	10/9	11/–
1943	12–12	12–0	11–7	12–0	16/2	15/6	15/8	15/7
1944	10–6	10–3	10–12	9–14	13/9	13/5	14/4	12/10
1945	12–8	12–13	11–13	12–0	16/4	16/11	15/10	15/10
Total	65–4	64–8	62–12	62–2	57/8	57/3	56/7	55/3
Mean	**10–14**	**10–12**	**10–7**	**10–6**	**14/5**	**14/4**	**14/2**	**13/10**

Waite Institute.

Merino.

	Mean weight of wool (in lb. and oz.).				Value (shillings and pence).			
	CO	CH	RO	RH	CO	CH	RO	RH
1940	13–11	12–15	12–11	13–2				
1941	13–13	13–9	13–9	13–15				
1942	16–3	16–2	15–5	16–11	20/1	21/–	18/10	21/2
1943	18–3	17–7	16–9	17–4	24/5	23/4	22/9	22/10
1944	9–15	10–4	8–12	8–14	13/3	14/2	11/7	12/–
1945	13–10	13–1	13–5	12–10	20/1	19/8	19/2	18/4
Total	85–7	83–6	80–3	82–8	77/10	78/2	72/4	74/4
Mean	**14–4**	**13–14**	**13–6**	**13–12**	**19/6**	**19/7**	**18/1**	**18/7**

Romney Marsh-Merino.

	Mean weight of wool (in lb. and oz.).				Value (shillings and pence).			
	CO	CH	RO	RH	CO	CH	RO	RH
1940	9–11	10–11	9–8	9–10				
1941	10–14	12–6	11–13	12–3				
1942	10–6	13–9	11–14	13–4	13/4	17/6	14/10	16/6
1943	13–2	14–8	14–5	14–13	19/–	20/10	20/7	19/9
1944	11–0	11–8	10–5	10–5	15/8	16/7	14/8	14/11
1945	13–15	13–8	13–10	12–7	20/9	20/10	20/8	18/7
Total	69–0	76–2	71–7	72–10	68/9	75/9	70/9	69/9
Mean	**11–8**	**12–11**	**11–15**	**12–2**	**17/2**	**18/11**	**17/8**	**17/5**

Quantities of hay produced and fed to the sheep.

Kybybolite.

	Total hay produced.		Hay fed to sheep.		Yield per ac.	
	CH	RH	CH	RH	CH	RH
	cwt. lb.	cwt. lb.	cwt. lb.	cwt. lb.	cwt. lb.	cwt. lb.
1940	11–24	8–8			4–31	3–8
1941	44–84	55–28	3–60	3–60	17–5	21–5
1942	95–56	77–84	15–42	15–28	36–43	29–69
1943	79–0	129–0	19–86	20–40	30–11	49–16
1944	9–101	12–2	18–84	22–106	3–86	4–65
1945	80–28	64–0	35–10	35–10	30–64	24–43
Total	320–69	346–10	92–58	97–20	122–16	131–94
Mean	**53–49**	**57–76**	**18–56**	**19–49**	**20–40**	**21–109**

Total hay production and yield of hay per ac.

Waite Institute.

	Total hay produced.		Yield per ac.	
	CH	RH	CH	RH
	cwt. lb.	cwt. lb.	cwt. lb.	cwt. lb.
1940	19–56	28–22	7–52	10–84
1941	40–11	39–45	15–32	15–4
1942	51–65	35–37	19–73	13–51
1943	89–77	61–0	34–19	23–27
1944	27–0	18–105	10–32	7–24
1945	63–0	59–4	24–0	22–55
Total	290–97	241–101	110–96	92–21
Mean	**48–54**	**40–36**	**18–53**	**15–49**

Mean yields of oven-dry herbage in cwt. per ac. (total of 2 cwts.), and percentage botanical composition, 1945.

Kybybolite.

Treatment.	Phalaris.	Wimmera rye-grass.	Sub. clover.	Annual legumes.	Miscellaneous.	Total.
CO yield	11·51	0·92	24·35	0·31	32·31	69·40
Per cent.	16·6	1·3	35·1	0·4	46·6	100·00
RO yield	16·21	1·06	17·93	1·69	27·63	64·52
Per cent.	25·1	1·7	27·8	2·6	42·8	100·00

Mean yields of oven-dry herbage in cwt. per ac. (November, 1945 cut only), and percentage botanical composition.

Kybybolite.

Treatment.	Phalaris.	Wimmera rye-grass.	Sub. clover.	Annual legumes.	Miscellaneous.	Total.
CO yield	6·13	0·61	21·98	0·30	17·09	46·11
Per cent.	13·3	1·3	47·7	0·6	37·1	100·00
CH yield	8·30	1·11	26·16	1·57	11·32	48·46
Per cent.	17·1	2·3	54·0	3·2	23·4	100·00
RO yield	8·95	0·78	16·15	1·63	15·85	43·36
Per cent.	20·6	1·8	37·2	3·8	36·6	100·00
RH yield	9·18	0·16	19·13	3·69	11·28	43·44
Per cent.	21·1	0·4	44·0	8·5	26·0	100·00

Mean yields of oven-dry herbage in cwt. per ac. (total of 2 cwt.) and percentage botanical composition, 1945.

Waite Institute.

Treatment.	Phalaris.	Wimmera rye-grass.	Sub. clover.	Annual legumes.	Miscellaneous.	Total.
CO yield	7·89	2·13	3·54	17·61	17·91	49·08
Per cent.	16·1	4·3	7·2	35·9	36·5	100·00
CH yield	9·82	0·10	3·76	9·09	20·58	43·35
Per cent.	22·6	0·2	8·7	21·0	47·5	100·00
RO yield	8·90	3·39	1·46	18·22	16·44	48·41
Per cent.	18·4	7·0	3·0	37·6	34·0	100·00
RH yield	8·48	0·02	1·73	11·69	19·84	41·76
Per cent.	20·3	0·1	4·1	28·0	47·5	100·00

15. YIELD AND COMPOSITION OF SOWN PASTURES WITH DIFFERENTIAL FERTILIZER TREATMENT UNDER IRRIGATION ON HEAVY LIGNUM-BOX FLATS.

Location: River flats under Lignum-box below 30 ft. lift from River Murray, Renmark, the property of G. Falland.

Preparation: Ploughing and grading, followed by grading into bays, 0·25 chains in width by 2 chains in length.

Species: Perennial rye-grass; Italian rye-grass; cocksfoot; prairie grass; phalaris, Rhodes grass; *Paspalum dilitatum, P. distichum, P. vaginatum; Cynodon dactylon; C. plectostachyum*, Kikuyu (non-seeding types), lucerne (non-creeping and creeping types); white, strawberry, red, alsike and subterranean clovers; barrel and black medics.

Date of Seeding: Pasture sown on 17th and 18th August, 1944.

Fertilizer treatment: Superphosphate 2 cwt. per ac. per annum as a basal dressing, plus

(a) Nil.
(b) Molybdenum trioxide, 2 oz., + copper sulphate, 4 lb., + zinc sulphate, 14 lb., per ac. per annum.
(c) Copper sulphate, 4 lb. per ac. + zinc sulphate, 14 lb. per ac. per annum.
(d) Molybdenum trioxide, 2 oz., + copper sulphate, 4 lb., + zinc sulphate, 14 lb., per ac. per annum.

Design: Each fertilizer treatment is confined to one irrigation bay. Main plots for fertilizer treatments are 0·25 × 2·00 chains in 3 randomized blocks of 1 × 2 chains. Pasture mixtures and single species in sub-plots 0·25 × 0·20 chains. Replications, 12. Plots sampled for yield and grazed at bi-monthly intervals.

DEVELOPMENT OF SEEDED PASTURES ON IRRIGABLE FLATS OF LOW LIFT FROM RIVER MURRAY, RENMARK, S.A. (1944–47).

(a) Seasonal Production.

Cwt. dry matter per ac.

(No. and incidence of cut.)

	1 Oct.-Nov.	2 Dec.-Jan.	3 Feb.-Mar.	4 Apl.-May.	5 June-July.	6 Aug.-Sept.	Total.
1. Pasture Mixtures.							
1944–45							
P	—	2·80	2·40	—	—	—	5·20
PMo	—	2·25	3·58	—	—	—	5·83
PMoCuZn	—	2·73	4·32	—	—	—	7·05
1945–46							
P	—	4·13	4·43	—	5·61	5·47	19·64
PMo	—	5·65	4·11	—	5·93	8·67	24·36
PMoCuZn	—	5·50	4·66	—	7·92	9·02	27·10
1946–47							
P	6·98	7·56	10·66	4·53	2·26	6·22	38·21
PMo	9·22	8·93	10·21	6·03	3·55	10·64	48·58
PMoCuZn	9·00	10·50	12·49	7·35	4·84	10·98	55·16

2. Lucerne.

			1944–45				
P	—	4·95	3·91	4·31	10·08	6·79	30·04
PMo	—	7·68	11·00	9·59	14·01	9·89	52·17
PMoCuZn	—	8·58	8·00	6·49	14·84	9·50	47·41
			1945–46				
P	14·01	6·06	4·03	—	6·33	6·74	37·17
PMo	19·09	9·46	7·42	—	9·31	11·83	57·11
PMoCuZn	20·53	9·65	6·75	—	8·76	10·46	56·15
			1946–47				
P	7·73	7·76	4·59	2·02	1·03	3·34	26·47
PMo	15·88	12·69	9·02	4·44	3·15	7·31	52·49
PMoCuZn	10·83	11·12	6·19	4·86	4·20	9·28	46·48

(b) Total Production.

Cwt. dry matter per ac.

Lucerne	P.	PMo.	PCuZn.	PMoCuZn.	Mean.
Lucerne (in mixtures)	**93·68**	**161·77**	**107·96**	**150·04**	**128·36**
1. Perennial rye-grass	43·99	55·24	29·58	80·77	52·39
2. Phalaris	33·92	29·28	51·09	49·92	41·05
3. Rhodes grass	35·82	67·83	43·65	36·81	46·03
Other legumes (in mixtures)					
1. With perennial rye-grass	1·43	2·08	8·78	7·48	4·94
2. With phalaris	1·63	4·25	2·94	8·83	4·41
3. With Rhodes grass	5·74	10·39	10·01	6·67	8·20
Main sown grasses (in mixtures)					
1. With perennial rye-grass	7·45	8·00	10·53	14·98	10·24
2. With phalaris	6·88	5·81	9·71	9·03	7·86
3. With Rhodes grass	48·76	42·24	58·23	42·07	47·83
Other sown grasses (in mixtures)					
1. With perennial rye-grass	1·51	3·83	1·43	3·73	2·62
2. With phalaris	2·02	3·83	2·48	7·14	3·88
3. With Rhodes grass	—	3·52	0·51	0·48	1·12
Totals of mixtures					
1. With perennial rye-grass	54·37	69·15	50·32	106·96	70·20
2. With phalaris	44·45	43·17	66·22	74·92	57·20
3. With Rhodes grass	90·33	123·98	112·40	86·04	103·19
Means of three mixtures (1–3) and lucerne					
Mixtures (1–3)	63·05	78·77	76·31	89·31	76·86
Mixtures (1–3) + lucerne	70·70	99·52	84·22	104·49	89·74

SIGNIFICANCE OF RESULTS.

Years: The yields of the mixtures and the grasses in the mixtures increased significantly each year; but this did not apply to lucerne sown alone.

Species: The order of productivity over the first three years was lucerne, Rhodes grass, perennial rye-grass, Phalaris.

Mo: Molybdenum significantly increased the yield of lucerne, sown alone, and of the Rhodes grass and perennial rye-grass mixtures.

CuZn: Copper + zinc significantly increased the yield of Phalaris, the Phalaris mixture and lucerne. The response of lucerne to CuZn was substantially lower than the response of this species to Mo.

Mo + CuZn: Although the yields with MoCuZn were generally greater over the experiment as a whole than those with either Mo or CuZn, there were significant negative interactions ($P < \cdot 01$) in the case of Rhodes grass mixture and lucerne sown alone or with Rhodes grass.